Effigies Reverendi admodum viri
Johannis Wilkins nuper Episcopi
Cestriensis

Effigies Reverendi admodum viri
Johannis Wilkins nuper Episcopi
Cestriensis

Mathematical Magick:

OR, THE

WONDERS

That may be performed by

Mechanichal Geometry.

In Two BOOKS.

CONCERNING

Mechanical { *Powers.* / *Motions.* }

Being one of the most easie, pleasant, useful (and yet most neglected) part of *Mathematicks.*

Not before treated of in this Language.

By *J. Wilkins*, late L^d B^p of *Chester.*

Τέχνῃ κρατοῦμεν ὧν φύσει νικώμεθα.

LONDON:

Printed for *Edw. Gellibrand* at the *Golden Ball* in St. *Pauls* Church-yard. 1680.

Jos: Banks

To His Highneſs the Prince Elector *Palatine.*

May it pleaſe Your Highneſs!

I *Should not thus have preſented my* diverſions, *where I owe my ſtudy and* buſineſs, *but that where all is due, a man may not juſtly withhold any part.*

This following Diſcourſe was compoſed ſome years ſince at my ſpare hours in the Univerſity. The Subject of it is mixed Mathematicks; *which I did the rather at ſuch times make choice of, as being for the* pleaſure *of it, more proper for recreation; and for the* facility, *more ſutable to my abilities and leiſure.*

I ſhould not, Sir, have been ambitious of any ſo Great (*I could not of any* Better) *Patronage, had not my relation both engaged and emboldned me to this Dedication.*

They that know your Highneſs how great an encourager you are, and how able

a Judge in all kind of ingenious arts and literature, muſt needs acknowledg your preſſures and low condition to be none of the leaſt miſchiefs (amongſt thoſe many other) under which the Commonwealth of Learning does now ſuffer.

It would in many reſpects much conduce to the general advancement of religion and learning, if the reformed Churches, in whoſe cauſe and defence your family hath ſo deeply ſuffered, were but effectually mindful of their engagements to it. And particularly, if theſe preſent unhappy differences of this Nation did not occaſion too much forgetfulneſs of their former zeal and profeſſions for the vindicating *of your family, and the* reſtoring *of your Highneſs; the haſtning and accompliſhment of which, together with the increaſe of all heavenly bleſſings upon your Highneſs, ſhall be the hearty daily prayer of*

Your Highneſs

Moſt humble and moſt devoted
ſervant and Chaplain,

JOHN WILKINS.

TO THE READER.

IT is related of *Heraclitus*, that when his Scholars had found him in a Tradesmans shop, whither they were ashamed to enter, He told them, *Quod neque tali loco dii desunt immortales*, that the gods were as well conversant in such places as in others; Intimating that a divine power and wisdome might be discerned even in those common arts, which are so much despised; And though the manual exercise and practise of them be esteemed ignoble, yet the study of their general causes and principles cannot be prejudical to any other (though the most sacred) profession.

It hath been my usual custom in the course of my other studies, to propose divers Mathematical or Philosophical inquiries, for the recreation of my leisure-hours; and as I could gather satisfaction, to compose them to some form and method.

Some of these have been formerly publi-

ſhed, and I have now ventured forth this diſcourſe; wherein beſides the great *delight and pleaſure* (which every rational Reader muſt needs find in ſuch notions as carry with them their own evidence and demonſtration) there is alſo much *real benefit* to be learned; particularly for ſuch Gentlemen as employ their eſtates in thoſe chargeable adventures of Drawning, Mines, Cole-pits, &c. who may from hence learn the chief grounds and nature of Engines, and thereby more eaſily avoid the deluſions of any cheating impoſtor: And alſo for ſuch *common Artizans*, as are well skilled in the practiſe of theſe arts, who may be much advantaged by the right underſtanding of their grounds and *Theory*.

Scho. Mathem. l. 2. *Ramus* hath obſerved, that the reaſon why *Germany* hath been ſo eminent for Mechanical inventions, is becauſe there have been publick Lectures of this kind inſtituted amongſt them, and thoſe not only in the learned languages, but alſo in the vulgar tongue, for the capacity of every unletter'd ingenious Artificer.

This whole Diſcourſe I call *Mathematical Magick*, becauſe the art of ſuch Mechanical inventions as are here chiefly inſiſted upon, hath been formerly ſo ſtyled; and in alluſion to vulgar opinion, which doth commonly attribute all ſuch ſtrange operations

Agrippa, De Vanit. Scient. c. 42, 43.

unto

unto the power of Magick; For which reason the Ancients did name this Art Θαυματοποιικὴ, or *Mirandorum Effectrix*.

The first book is called *Archimedes*, because he was the chiefest in discovering of Mechanical *powers*.

The second is styled by the name of *Dædalus*, who is related to be one of the first and most famous amongst the Ancients for his skill in making *Automata*, or self-moving Engines: both these being two of the first Authors that did reduce Mathematical principles unto Mechanical experiments.

Other discourses of this kind, are for the most part large and voluminous, of great price and hardly gotten; and besides, there are not any of them (that I know of) in our vulgar tongue, for which these Mechanical arts of all other are most proper. These inconveniences are here in some measure remedied, together with the addition (if I mistake not) of divers things very considerable, and not insisted upon by others.

The

The Contents and Method of this following Discourse.

The first Book.

Chap. 1. *THe excellency of these Arts. Why they were concealed by the Ancients. The Authors that have treated of them.*

Ch. 2. *Concerning the name of this Art. That it may properly be styled liberal. The subject and nature of it.*

Ch. 3. *Of the first Mechanical faculty, the* Ballance.

Ch. 4. *Concerning the second Mechanick faculty, the* Leaver.

Ch. 5. *How the natural motion of living creatures is conformable to these artificial rules.*

Ch. 6.

Ch. 6. *Concerning the* Wheel.

Ch. 7. *Concerning the* Pulley.

Ch. 8. *Of the* Wedg.

Ch. 9. *Of the* Screw.

Ch. 10. *An inquiry into the magnificent works of the Ancients, which much exceeding our later times may seem to infer a decay in these Mechanical arts.*

Ch. 11. *That the Ancients had diver* motives *and* means *for such vast magnificent works, which we have not.*

Ch. 12. *Concerning the force of the Mechanick faculties; particularly, the* Ballance *and* Leaver. *How they may be contrived to move the whole world, or any other conceivable weight.*

Ch. 13. *Of the* Wheel, *by multiplication of which, it is easie to move any imaginable weight.*

Ch. 14. *Concerning the infinite ſtrength of* Wheels, Pulleys, *and* Screws; *that it is poſſible by the multiplication of theſe, to pull up any Oak by the roots with a hair, lift it up with a ſtraw, or blow it up with ones breath, or to perform the greateſt labour with the leaſt power.*

Ch. 15. *Concerning the proportion of ſlowneſs and ſwiftneſs in Mechanical motions.*

Ch. 16. *That it is poſſible to contrive ſuch an artificial motion as ſhall be of a ſlowneſs proportionable to the ſwiftneſs of the heavens.*

Ch. 17. *Of ſwiftneſs, how it may be increaſed to any kind of proportion. Concerning the great force of* Archimedes *his Engines. Of the* Balliſta.

Ch. 18. *Concerning the* Catapultæ, *or Engines for Arrows.*

Ch. 19. *A compariſon betwixt theſe ancient*

ancient Engines, and the Gun-powder instruments now in use.

Ch. 20. *That it is possible to contrive such an artificial motion, as may be equally swift with the supposed motion of the heavens.*

The second Book.

Ch. 1. THE *divers kinds of* Automata, *or Self-movers: Of Mills. Of the contrivance of several motions by rarified air. A brief digression concerning Wind-guns.*

Ch. 2. *Of a sailing Chariot, that may without horses be driven on the land by the wind, as ships are on the sea.*

Ch. 3. *Concerning the fixed* Automata, *Clocks, Spheres representing the heavenly motions. The several excellencies that are most commendable in such kind of contrivances.*

Ch. 4. *Of the movable and gradient* Automata, *repreſenting the motion of living creatures, various ſounds, of birds, or beaſts, and ſome of them articulate.*

Ch. 5. *Concerning the poſſibility of framing an Ark for ſubmarine Navigations. The Difficulties and Conveniences of ſuch a contrivance.*

Ch. 6. *Of the volant* Automata; Archytas *his Dove, and* Regiomontanus *his Eagle. The poſſibility and great uſefulneſs of ſuch inventions.*

Ch. 7. *Concerning the Art of flying. The ſeveral ways whereby this hath been, or may be attempted.*

Ch. 8. *A reſolution of the two chief difficulties that ſeem to oppoſe the poſſibility of a flying Chariot.*

Ch. 9. *Of a perpetual motion. The ſeeming facility and real difficulty of any ſuch contrivance. The ſeveral ways*

ways whereby it hath been attempted, particularly by Chymistry.

Ch. 10. *Of subterraneous Lamps, divers historical relations concerning their duration for many hundred years together.*

Ch. 11. *Several opinions concerning the nature and reason of these perpetual Lamps.*

Chap. 12. *The most probable conjecture how these Lamps were framed.*

Ch. 13. *Concerning several attempts of contriving a perpetual motion by magnetical virtues.*

Chap. 14. *The seeming probability of effecting a continual motion by solid weights in a hollow wheel or sphere.*

The Contents.

Ch. 15. *Of composing a perpetual motion by fluid weights. Concerning* Archimedes *his water-screw. The great probability of accomplishing this inquiry by the help of that, with the fallibleness of it upon experiment.*

ARCHI-

ARCHIMEDES,
OR,
Mechanical Powers.

The first Book.

CHAP. I.

The excellency of these Arts. Why they were concealed by the Ancients. The Authors that have treated of them.

ALL those various studies about which the sons of men do busie their endeavours, may be generally comprised under these three kinds:

- Divine.
- Natural.
- Artificial.

To the first of these, is reducible, not only the *speculation* of Theological truths, but also the *practise* of those virtues which may advantage our minds in the enquiry after their proper happiness. And these arts alone may truly be styled liberal, *Quæ liberum faciunt homines, quibus curæ virtus est*, (saith the divine Stoick) which set a man at liberty from his lusts and passions.

Sen. Ep. 88.

To the second may be referred all that knowledg which concerns the frame of this great Universe, or the usual course of providence in the government of these created things.

To the last do belong all those inventions, whereby nature is any way quickned or advanced in her defects: These artificial experiments being (as it were) but so many Essays, whereby men do naturally attempt to restore themselves from the first general curse inflicted upon their labours.

This following Discourse, does properly appertain to this latter kind.

Now

Now Art may be ſaid, either to *imitate* nature, as in limming and pictures; or to *help* nature, as in medicine; or to *overcome* and *advance* nature, as in theſe Mechanical diſciplines, which in this reſpect are by ſo much to be preferred before the other, by how much their end and power is more excellent. Nor are they therefore to be eſteemed leſs noble, becauſe more practical, ſince our beſt and moſt divine knowledg is intended for action, and thoſe may juſtly be counted barren ſtudies, which do not conduce to practiſe as their proper end.

But ſo apt are we to contemn every thing which is common, that the ancient Philoſophers eſteemed it a great part of wiſdom, to conceal their learning from vulgar apprehenſion or uſe, thereby the better to maintain it in its due honour and reſpect. And therefore did they generally vail all their Arts and Sciences, under ſuch myſtical expreſſions, as might excite the peoples wonder

and reverence, fearing leſt a more eaſie and familiar diſcovery, might expoſe them to contempt. *Sic ipſa myſteria fabularum cuniculis operiuntur, ſummatibus tantum viris, ſapientiæ interprete, veri arcani conſciis; Contemti ſint reliqui, ad venerationem, figuris defendentibus à vilitate ſecretum,* ſaith a Platonick.

Macrobius Somn. Scip. l. 1. c. 2.

Hence was it, that the ancient Mathematicians did place all their learning in abſtracted ſpeculations, refuſing to debaſe the principles of that noble profeſſion unto Mechanical experiments. Inſomuch, that thoſe very Authors amongſt them, who were moſt eminent for their inventions of this kind, and were willing by their own practiſe, to manifeſt unto the world thoſe artificial wonders that might be wrought by theſe arts, as *Dædalus, Archytas, Archimedes, &c.* were notwithſtanding ſo much infected with this blind ſuperſtition, as not to leave any thing in writing concerning the grounds and manner of theſe operations.

Quin-

Quintilian ſpeaking to this purpoſe of *Archimedes*, ſaith thus: *Quamvis tantum tamque ſingularem Geometriæ uſum, Archimedes, ſingularibus exemplis, & admirandis operibus oſtenderit, propter quæ non humanæ ſed divinæ ſcientiæ laudem ſit adeptus, hæſit tamen in illa Platonis perſuaſione, nec ullam Mechanicam literam prodere voluit.* *Quint. l. 1 c. 10.*

By which means, poſterity hath unhappily loſt, not only the benefit of thoſe particular diſcoveries, but alſo the proficiency of thoſe arts in general. For when once the learned men did forbid the reducing of them to particular uſe and vulgar experiment, others did thereupon refuſe theſe ſtudies themſelves, as being but empty and uſeleſs ſpeculations. Whence it came to paſs, that the ſcience of Geometry was ſo univerſally neglected, receiving little or no addition for many hundred years together. *Pet. Ram. Schol. Mathem. l. 1*

Amongſt theſe Ancients, the divine *Plato* is obſerved to be one of the greateſt ſticklers for this fond

opinion, ſeverely dehorting all his followers from proſtituting Mathematical principles, unto common apprehenſion or practiſe. Like the envious Emperour *Tiberius*, who is reported to have killed an Artificer for making glaſs malleable, fearing leſt thereby the price of metals might be debaſed. So he, in his ſuperſtition to Philoſophy, would rather chuſe to deprive the world of all thoſe uſeful and excellent inventions which might be thence contrived, than to expoſe that profeſſion unto the contempt of the ignorant vulgar.

Plin. Nat. l. 36. c. 26.

But his Scholar *Ariſtotle*, (as in many other particulars, ſo likewiſe in this) did juſtly oppoſe him, and became himſelf one of the firſt Authors that hath writ any methodical Diſcourſe concerning theſe arts; chuſing rather a certain and general benefit, before the hazard that might accrue from the vain and groundleſs diſreſpects of ſome ignorant perſons. Being ſo far from eſteeming Geometry diſhonoured by the applicati-

Ariſt. Quæſt. Mechan.

on

on of it to Mechanical practiſes, that he rather thought it to be thereby adorned, as with curious variety, and to be exalted unto its natural end. And whereas the Mathematicians of thoſe former ages, did poſſeſs all their learning, as covetous men do their wealth, only in thought and notion; the judicious *Ariſtotle*, like a wiſe Steward, did lay it out to particular uſe and improvement, rightly preferring the reallity and ſubſtance of publick benefit, before the ſhadows of ſome retired ſpeculation, or vulgar opinion.

Since him there have been divers other Authors, who have been eminent for their writings of this nature. Such were *Hero Alexandrinus*, *Hero Mechanicus*, *Pappus Alexandrinus*, *Proclus Mathematicus*, *Virtuvius*, *Guidus Ubaldus*, *Henricus Monantholius*, *Galileus*, *Guevara*, *Merſennus*, *Bettinus*, *&c.* Beſides many others, that have treated largely of ſeveral engines, as *Auguſtine Ramelli*, *Vittorio Zoncha*, *Jacobus Beſſonius*, *Vegetius*, *Lipſius*.

Most of which Authors I have perused, and shall willingly acknowledge my self a debtor to them for many things in this following Discourse.

CAP. II.

Concerning the name of this Art. That it may properly be styled liberal. The subject and nature of it.

Lypsius. Polyorcet. l. 1. Dialog. 3. That's a sensless absurd Etymology imposed by some, *Quia intellectus in eis mœchasur*, as if these arts did prostitute and adulterate the understanding.

THe word *Mechanick* is thought to be derived ἀπὸ τῦ μήκους καὶ ἄνειν, *multum ascendere, pertingere:* intimating the efficacy and force of such inventions. Or else παρὰ μὴ χαίνειν (saith *Eustathius*) *quia hiscere non sinit*, because these arts are so full of pleasant variety, that they admit not either of sloth or weariness.

According to ordinary signification, the word is used in opposition to the liberal arts: whereas in propriety of speech those employments alone may be styled *illiberal*, which require onely some bodily exercise, as manufactures, trades, &c. And on the con-

contrary, that diſcipline which diſcovers the general cauſes, effects, and properties of things, may truly be eſteemed as a *ſpecies* of Philoſophy.

But here it ſhould be noted, that this art is uſually diſtinguiſhed into a twofold kind:

1. *Rational.*
2. *Cheirurgical.*

Pappus Proem. in Collect. Mathem. l. 8.

The *Rational* is that which treats of thoſe principles and fundamental notions, which may concern theſe Mechanical practiſes.

The *Cheirurgical* or *Manual*, doth refer to the making of theſe inſtruments, and the exerciſing of ſuch particular experiments. As in the works of Architecture, Fortifications, and the like.

The firſt of theſe, is the ſubject of this diſcourſe, and may properly be ſtiled *liberal*, as juſtly deſerving the proſecution of an ingenuous mind. For if we conſider it according to its birth and original, we ſhall find it to ſpring from honourable parentage, being produced by *Geometry* on the one

one ſide, and *natural Philoſophy* on the other. If according to its uſe and benefit, we may then diſcern that to this ſhould be referred all thoſe arts and profeſſions ſo neceſſary for humane ſociety, whereby nature is not only directed in her uſual courſe, but ſometimes alſo commanded againſt her own law. The particulars that concern Architecture, Navigation, Husbandry, Military affairs, &c. are moſt of them reducible to this art, both for their invention and uſe.

Thoſe other diſciplines of Logick, Rhetorick, &c. do not more protect and adorn the mind, than theſe Mechanical powers do the body.

And therefore are they well worthy to be entertained with greater induſtry and reſpect, than they commonly meet with in theſe times; wherein there be very many that pretend to be maſters in all the liberal arts, who ſcarce underſtand any thing in theſe particulars.

The ſubject of this art is concerning the heavineſs of ſeveral bodies, or

or the proportion that is required betwixt any weight, in relation to the power which may be able to move it. And so it refers likewise to violent and artifical motion, as Philosophy doth to that which is natural.

The proper end for which this art is intended, is to teach how by understanding the true difference betwixt the *weight* and the *power*, a man may add such a fitting supplement to the strength of the power, that it shall be able to move any conceivable weight, though it should never so much exceed that force which the power is naturally endowed with.

The art it self may be thus described to be a Mathematical discipline, which by the help of Geometrical principles doth teach to contrive several weights and powers, unto any kind, either of motion or rest, according as the Artificer shall determine.

If it be doubted how this may be esteemed a *species* of Mathematicks, when as it treats of weights, and not of

Dav. Rivaltus præf. in lib. Archim. de centro gravitatis.

of quantity; For ſatisfaction to this, there are two particulars conſiderable.

1. *Mathematicks* in its latitude is uſually divided into *pure* and *mixed*. And though the *pure* do handle onely *abſtract quantity* in the *general*; as *Geometry*, *Arithmetick*: yet that which is *mixed* doth conſider the quantity of ſome *particular determinate* ſubject. So *Aſtronomy* handles the quantity of heavenly motions, *Muſick* of ſounds, and *Mechanicks* of weights & powers.

2. Heavineſs or weight is not here conſidered, as being ſuch a natural *quality*, whereby condenſed bodies do of themſelves *tend downwards*; but rather as being an affection, whereby they may be meaſured. And in this ſenſe *Ariſtotle* himſelf refers it amongſt the other *ſpecies* of *quantity*, as having the ſame proper eſſence, which is to be compounded of integral parts. So a pound doth conſiſt of ounces, drams, ſcruples. Whence it is evident, that there is not any ſuch repugnancy in the ſubject of this art, as may hinder it from being a true *ſpecies* of *Mathematicks*.

Metaph. l. 10. c. 2.

CAP.

CAP. III.

Of the first Mechanical faculty, the Ballance.

THE Mechanical faculties, by which the experiments of this nature must be contrived, are usually reckoned to be these six:

1. *Libra.*	1. *The Ballance.*
2. *Vectis.*	2. *The Leaver.*
3. *Axis in Peritrochio.*	3. *The Wheel.*
4. *Trochlea.*	4. *The Pulley.*
5. *Cuneus.*	5. *The Wedg.*
6. *Cochlea.*	6. *The Screw.*

Unto some of which, the force of all Mechanical inventions must necessarily be reduced. I shall speak of them severally and in this order.

First concerning the Ballance; this and the Leaver are usually confounded together, as being but one faculty, because the general grounds and proportions of either force is so exactly the same. But for better distinction, and

more

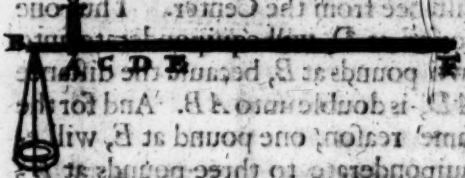
more clear discovery of their natures, I shall treat of them severally.

The first invention of the ballance is commonly attributed to *Astrea*, who is therefore deified for the goddess of Justice; and that instrument it self advanced amongst the celestial signs.

The particulars concerning it are so commonly known, and of such easie experiment, that they will not need any large explication. The chief end and purpose of it, is for the distinction of several ponderosities; For the understanding of which, we must note, that if the length of the sides in the Ballance, and the weights at the ends of them, be both mutually equal, then the Beam will be in a horizontal situation. But on the contrary, if either the weights alone be equal, and not their distances, or the distances alone, and not the weights, then the Beam will accordingly decline.

As in this following diagram.

Sup-



Suppose an equal weight at *C*, unto that at *B*, (which points are both equally distant from the center *A*,) it is evident that then the beam *B F*, will hang horizontally. But if the weight supposed at *C*, be unequal to that at *B*, or if there be an equal weight at *D E*, or any of the other unequal distances; the Beam must then necessarily decline.

With this kind of Ballance, it is usual by the help only of one weight, to measure sundry different gravities, whether more or less, than that by which they are measured. As by the example here described, a man may with one pound alone, weigh any other body within ten pounds, because the heaviness of any weight doth

Cardan. Subtil. l. 1.

doth increaſe proportionably to its diſtance from the Center. Thus one pound at *D*, will equiponderate unto two pounds at *B*, becauſe the diſtance *A D*, is double unto *A B*. And for the ſame reaſon, one pound at *E*, will equiponderate to three pounds at *B*; and one pound at *F*, unto ten at *B*, becauſe there is ſtill the ſame diſproportion betwixt their ſeveral diſtances.

This kind of Ballance is uſually ſtyled *Romana*, *ſtatera*. It ſeems to be of ancient uſe, and is mentioned by *Ariſtotle* under the name of ὁλκάς.

Mechan. ca. 21.

Hence it is eaſie to apprehend, how that falſe ballance may be compoſed, ſo often condemned by the wiſe man, as being an abomination to the Lord. If the ſides of the Beam be not equally divided, as ſuppoſe one have 10 parts, and the other 11, then any two weights that differ according to this proportion, (the heavier being placed on the ſhorter ſide, and the lighter on the longer) will equiponderate. And yet both the ſcales being empty, ſhall hang in *æquilibrio*,

Prov. 11.1 *ca.* 16.11. *Item. cap.* 20.10.23. *Pappus. Collect. Mathem. l.* 8.

as if they were exactly just and true, as in this description.

Suppose *AC*, to have 11 such parts, whereof *AB*, has but 10, and yet both of them to be in themselves of equal weight; it is certain, that whether the scales be empty, or whether in the scale *D*, we put 11 pound, and at *E* 10 pound, yet both of them shall equiponderate, because there is just such a disproportion in the length of the sides *AC*, being unto *AB*, as 11 to 10.

The frequency of such cozenages in these dayes, may be evident from common experience: and that they were used also in former ages, may

 appear

Quæstion. Mechan. c. 2. Budæus. appear from *Aristotles* testimony concerning the Merchants in his time. For the remedying of such abuses the Ancients did appoint divers Officers styled ζυγοστάται, who were to overlook the common measures.

Hence the proverb *Zygostatica fides.*

So great care was there amongst the Jews for the preservation of commutative justice from all abuse and falsification in this kind, that the publick standards and originals by which all other measures were to be tryed and allowed, were with much religion preserved in the Sanctuary, the care of them being committed to the Priests and Levites, whose office it was to look unto *all manner of measures and size.* Hence is that frequent expression, *According to the shekel of the Sanctuary*; and that Law, *All thy estimations shall be according to the shekel of the Sanctuary*, which doth not refer to any weight or coin, distinct from, and more than the vulgar, (as some fondly conceive) but doth only oblige men in their dealing and traffique to make use of such just

1 Chron. 23. 29.

Exod. 30. 3.

Lev. 27. 25

just measures, as were agreeable unto the publick standards that were kept in the Sanctuary.

The manner how such deceitful ballances may be discovered, is by changing the weights into each other scale, and then the inequality will be manifest.

From the former grounds rightly apprehended, it is easie to conceive how a man may find out the just proportion of a weight, which in any point given, shall equiponderate to several weights given, hanging in several places of the Beam.

Some of these ballances are made so exact (those especially which the refiners use) as to be sensibly turned with the eightieth part of a grain: which (though it may seem very strange) is nothing to what *Capellus relates of one at *Sedan*, that would turn with the four hundredth part of a grain.

Master Greaves, Roman foot.

* *De ponderibus & nummis*, l. 1.

There are several contrivances to make use of these in measuring the weight of blows, the force of powder,

J Banks 1759

the strength of strings, or other oblong substances, condensed air, the distinct proportion of several metals mixed together, the different gravity of divers bodies in the water, from what they have in the open air, with divers the like ingenious inquiries.

CAP. IV.

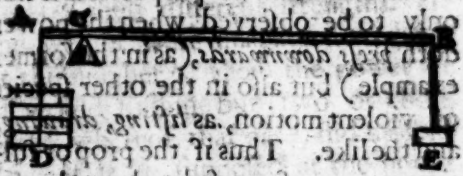
Concerning the second Mechanick faculty, the Leaver.

THE second Mechanical faculty, is the Leaver; the first invention of it is usually ascribed to *Neptune*, and represented by his Trident, which in the Greek are both called by one name, and are not very unlike in form, being both of them somewhat broader at one end, than in the other parts.

There is one main principle concerning it, which is (as it were) the very sum and epitome of this whole art. The meaning of it is thus expressed by *Aristotle*, ὁ τὸ κινοῦμενον βάρος πρὸς τὸ κινοῦν τὸ μῆκος πρὸς τὸ μῆκος ἀντιπεπονθεῖν. That is,

μόχλος. *Aristotle Quæst. Mechan. cap. 4. Archimedes, de Æquiponderant. l. 1. prop. 7. Vitruvius Architect. l. 10 c. 8.*

is, as the weight is to an equivalent power, so is the distance betwixt the weight and the center, unto the distance betwixt the center and the power, and so reciprocally. Or thus, the power that doth equiponderate with any weight, must have the same proportion unto it, as there is betwixt their several distances from the center or fulciment; as in this following figure.



Where suppose the Leaver to be represented by the length *A B*, the center or* prop at the point *C*, the weight to be sustained *D*, the power that doth uphold it *E*.

Now the meaning of the foresaid principle doth import thus much, that the power at *E*, must bear the same

* This *Aristotle* calls ὑπομόχλιον. *Vitruvius*, *Pressio*. *Ubaldus*, *Fulcimentum*, *Dan. Barbarus*, *Scabellum*

same proportion to the weight D, as the distance CA, doth to the other CB; which, because it is octuple in the present example, therefore it will follow that one pound at B, or E, will equiponderate to eight pounds at A, or D, as is expressed in the figure. The ground of which maxime is this, because the point C is supposed to be the center of gravity, on either side of which, the parts are of equal weight.

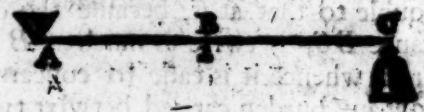
And this kind of proportion is not only to be observed when the power doth *press downwards*, (as in the former example) but also in the other species of violent motion, as *lifting*, *drawing*, and the like. Thus if the prop or fulciment were supposed to be at the extremity of the Leaver,

As in this Diagram at *A*, then the weight *B*, would require such a difference in the strengths or powers that did sustain it, as there is betwixt the several distances *A C*, and *B C*. For as the distance *A B*, is unto *A C*, so is the power at *C*, to the weight at *B*; that is, the power at *A*, must be double to that at *C*, because the distance *B C*, is twice as much as *B A*. From whence it is easie to conceive, how any burden carried betwixt two persons, may be proportioned according to their different strengths. If the weight were imagained to hang at the number 2, then the power at *C*, would sustain but two of those parts, whereof that at *A*, did uphold 16. If it be supposed at the figure (3) then the strength at *C*, to that at *A*, would be but as three to fifteen. But if it were situated at the figure (9) then each of the extremities would participate of it alike, because that being the middle, both the distances are equal. If at the number (12) then the strength at *C*, is required to be

The right understanding of this doth much conduce to the explication of the Pulley.

double unto that at *A*. And in the like manner are we to conceive of the other intermediate divſions.

Thus alſo muſt it be, if we ſuppoſe the power to be placed betwixt the fulciment and the weight, as in this example.



Where, as *AC*, is to *AB*, ſo is the power at *B*, to the weight at *C*.

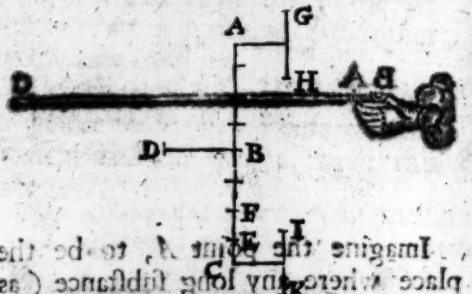
Hence likewiſe may we conceive the reaſon why it is much harder to carry any long ſubſtance, either on the ſhoulders, or in the hand, if it be held by either of the extremes, than if it be ſuſtained by the middle of it. The ſtrength that muſt equiponderate at the nearer end, ſometimes increaſing the weight almoſt double to what it is in it ſelf.

Imagine

Imagine the point *A*, to be the place where any long ſubſtance (as ſuppoſe a Pike) is ſuſtained, it is evident from the former principle, that the ſtrength at *B*, (which makes it lye level) muſt be equal to all the length *AC*, which is almoſt the whole Pike.

And as it is in the depreſſing, or elevating, ſo likewiſe is it in the drawing of any weight, as a Coach, Plow, or the like.

Let



Let the line *D B* represent the Pole or Carriage on which the burden is sustained, and the line *A C*, the cross barre; at each of its extremities there is a several spring-tree *G H*, and *I K*, to which either horses or oxen may be fastned. Now because *A* and *C* are equally distant from the middle *B*, therefore in this case the strength must be equal on both sides; but if we suppose one of these spring-trees to be fastned unto the points *E*, or *F*, then the strength required to draw on that side, will be so much more, as the distance *E B*, or *F B*, is less than that of *A B*; that is, either as three or four, as *E B*, to *B A*,

B A, or as one to two, as *F B*, to *B A*. So that the beast fastned at *A*, will not draw so much by a quarter, as the other at *E*, and but half as much as one at *F*.

Whence it is easie to conceive how a husbandman (*cum inæquales veniunt ad aratra juvenci*) may proportion the labour of drawing according to the several strength of his oxen.

Unto this Mechanical faculty should be reduced sundry other instruments in common use. Thus the oares, stearn, masts, &c. according to their force, whereby they give motion to the ship, are to be conceived under this head.

Arist. Mechan. c. 5, 6, 7. Vide Guevar. Comment.

Thus likewise for that engine, whereby Brewers and Dyers do commonly draw water, which *Aristotle* calls πλόνιον and others *Tollenon*. This being the same kind of Instrument, by which *Archimedes* drew up the ships of *Marcellus*.

Mechan. c. 29. Pet. Crinitus, de honesta Disciplina l. 19. c. 2. calls it corruptly *Tellenon.*

CAP.

CAP. V.

How the natural motion of living creatures is conformable to these artificial rules.

THE former Principle being already explained, concerning artificial and dead motions, it will not be altogether impertinent, if in the next place, we apply it unto those that are natural in living bodies, and examine whether these also are not governed by the same kind of proportions.

In all perfect living creatures, there is a twofold kind of motive instruments.

1. Primary, the muscles.
2. Secondary, the members.

The muscles are naturally fitted to be instruments of motion, by the manner of their frame and composure; consisting of flesh as their chief material, and besides of Nerves, Ligatures, Veins, Arteries, and Membrances,

The

The *Nerves* ſerve for the conveyance of the motive faculty from the brain. The *Ligatures* for the ſtrengthning of them, that they may not flag and languiſh in their motions. The *Veins* for their nouriſhment. The *Arteries* for the ſupplyiug of them with ſpirit, and natural vigor. The *Membrances* for the comprehenſion or incloſure of all theſe together, and for the diſtinction of one muſcle from another. There are beſides divers *fibræ* or hairy ſubſtances, which nature hath beſtowed for the farther corroborating of their motions; theſe being diſperſed through every muſcle, do ſo joyn together in the end of them, as to make intire nervous bodies, which are called *Tendones*, almoſt like the griſles. Now this (ſaith *Galen*) may fitly be compared to the broader part of the Leaver, that is put under the weight, which, as it ought to be ſo much the ſtronger, by how much it is put to a greater force; ſo likewiſe by this doth nature inable the muſcles and nerves

De Placit. Hippoc. & Platon. l. 10 ca. 10.

for

for those motions, which otherwise would be too difficult for them.

Whence it may evidently appear, that according to the opinion of that eminent Physitian, these natural motions are regulated by the like grounds with the artificial.

Thus also is it in those secondary instruments of motion, the members: amongst which, the hand is ὀργανον ὀργανων, the instrument of instruments (as *Galen* styles it); and as the soul of man doth bear in it the image of the divine wisdome and providence, so this part of the body seems in some sort to represent the Omnipotency of God, whilst it is able to perform such various and wonderful effects by the help of this art. But now for its own proper natural strength, in the lifting any great weight, this is always proportioned according to its extension from the body, being of least force when it is fully stretched out, or at arms end, (as we say) because then the shoulder joynt is as the center of its

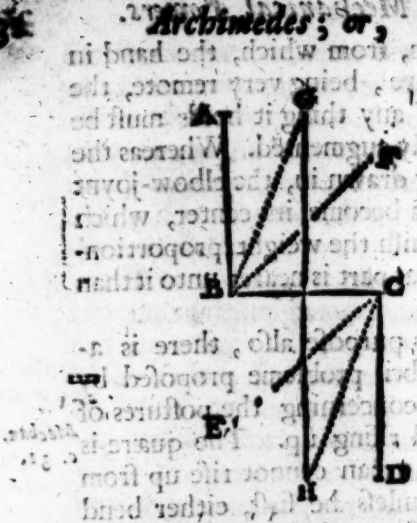
De usu partium. l. 1. c. 2.

its motion, from which, the hand in that posture, being very remote, the weight of any thing it holds must be accordingly augmented. Whereas the arm being drawn in, the elbow-joynt doth then become its center, which will diminish the weight proportionably, as that part is nearer unto it than the other.

To this purpose also, there is another subtil problome proposed by *Aristotle*, concerning the postures of sitting and rising up. The quære is this, Why a man cannot rise up from his seat, unless he first, either bend his body forward, or thrust his feet backward. *Mechan. c.* 31.

In the posture of sitting, our legs are supposed to make a right angle with our thighs, and they with our backs, as in this figure.

Where



Where let *AB*, represent the back, *BC*, the thighs, *CD*, the legs. Now it is evident, that a man cannot rise from this posture, unless either the back *AB*, do first incline unto *F*, to make an acute angle with the thighs *BC*; or else that the legs *CD*, do incline towards *E*, which may also make an acute angle with the thighs *BC*; or, lastly, unless both of them do decline to the points *G H*, where they may be included in the same perpendicular.

For

For the resolution of which, the Philosopher proposes these two particulars.

1. A right angle (saith he) is a kind of equality, and that being naturally the cause of rest, must needs be an impediment to the motion of rising.

2. Because when either of the parts are brought into an acute angle, the head being removed over the feet, or they under the head; in such a posture the whole man is much nearer disposed to the form of standing, wherein all these parts are in one streight perpendicular line, than he is by the other of right angles, in which the back and legs are two parallels; or that of turning these streight angles into obtuse, which would not make an erect posture, but declining.

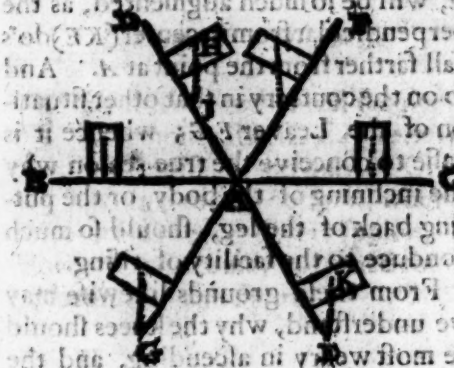
But neither of these particulars (as I conceive) doe fully satisfie the present quære, neither do the Commentators, *Monantholius*, or *Guevara*, better resolve it. Rather suppose *B C*, to be as a Vectis or Leaver, to-

wards the middle of which is the place of the fulciment, *A B*, as the weight, *C D*, the power that is to raise it.

Now the body being situate in this rectangular form, the weight *A B*, must needs be augmented proportionably to its distance from the fulciment, which is about half the thighs; whereas if we suspose either the weight to be inclined unto *F*, or the power to *E*, or both of them to *G H*, then there is nothing to be lifted up but the bare weight it self, which in this situation is not at all increased with any addition by distance.

For in these conclusions concerning the Leaver, we must always imagine that point which is touched by a perpendicular from the center of gravity, to be one of the terms. So that the diverse elevation or depression of the instrument, will infer a great alteration in the weight it self, as may more clearly be discerned by this following Diagram.

Where



Where *A*, is ſuppoſed to be the place of the prop or fulciment, *B C*, a Leaver which ſtands horizontally, the power and the weight belonging unto it, being equal both in themſelves, and alſo in their diſtances from the prop.

But now ſuppoſe this inſtrument to be altered according to the ſituation *D E*, then the weight *D*, will be diminiſhed, by ſo much, as the perpendicular from its center of gra-

vity *H I*, doth fall nearer to the prop or fulciment at *A*. And the power at *E*, will be ſo much augmented, as the perpendicular from its center (*K E*) do's fall farther from the point at *A*. And ſo on the contrary in that other ſituation of the Leaver *F G*; whence it is eaſie to conceive the true reaſon, why the inclining of the body, or the putting back of the leg, ſhould ſo much conduce to the facility of riſing.

Sir *Fran Bacons Nat. Hiſt. Exp.* 731.

From theſe grounds likewiſe may we underſtand, why the knees ſhould be moſt weary in aſcending, and the thighs in deſcending; which is becauſe the weight of the body doth bear moſt upon the knee-joynts, in raiſing it ſelf up, and moſt upon the muſcles of the thighs when it ſtays it ſelf in coming down.

There are divers other natural problemes to this purpoſe, which I forbear to recite. We do not ſo much as go, or ſit, or riſe, without the uſe of this Mechanical Geometry.

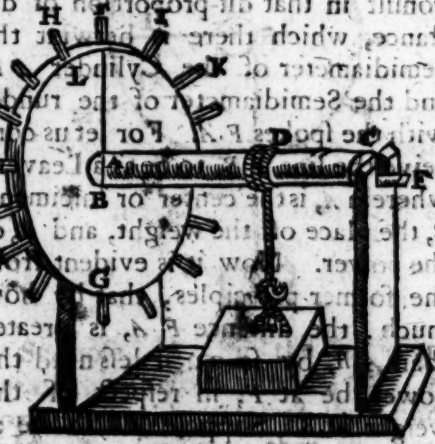
CAP.

CAP. VI.

Concerning the Wheel.

THe third Mechanical faculty is commonly stiled *axis in peritrochio.* It consists of an axis or Cylinder, having a rundle about it, wherein there are fastened divers spokes, by which the whole may be turned round; according to this figure.

Called likewise ὄνκ *Arist. Mechan. c.* 14.

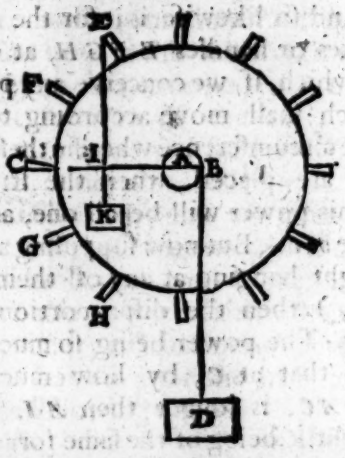


Where *B C*, does repreſent the Cylinder which is ſuppoſed to move upon a ſmaller Axis at *E*, (this being all one in compariſon to the ſeveral proportions, as if it were a meer Mathematical line) *L G*, is the rundle or wheel, *H F I K*, ſeveral ſpokes or handles that are faſtned in it; *D*, the place where the cord is faſtned for the drawing or lifting up of any weight.

The force of this inſtrument doth conſiſt in that diſ-proportion of diſtance, which there is betwixt the Semidiameter of the Cylinder *A B*, and the Semidiameter of the rundle with the ſpokes *F A*. For let us conceive the line *F B*, to be as a Leaver, wherein *A*, is the center or fulciment, *B*, the place of the weight, and *F*, of the power. Now it is evident from the former principles, that by how much the diſtance *F A*, is greater than *A B*, by ſo much leſs need the power be at *F*, in reſpect of the weight at *B*. Suppoſe *A B*, to be as the tenth part of *A F*, then the power

er or ſtrength: which is but as a hundred pound at *F*, will be equal to a thouſand pound at *B*.

For the clearer explication of this faculty, it will not be amiſs to conſider the form of it, as it will appear being more fully expoſed to the view. As in this other Diagram.



Suppoſe *AB*, for the Semidiameter of the Axis or Cylinder, and *AC*, for the Semidiameter of the rundle, with the ſpokes; then the power

at *C*, which will be able to ſupport the weight *D*, muſt bear the ſame proportion unto it, as *A B*, doth to *A C*: ſo that by how much ſhorter the diſtance *A B*, is in compariſon to the diſtance *A C*, by ſo much leſs need the power be at *C*, which may be able to ſupport the weight *D*, hanging at *B*.

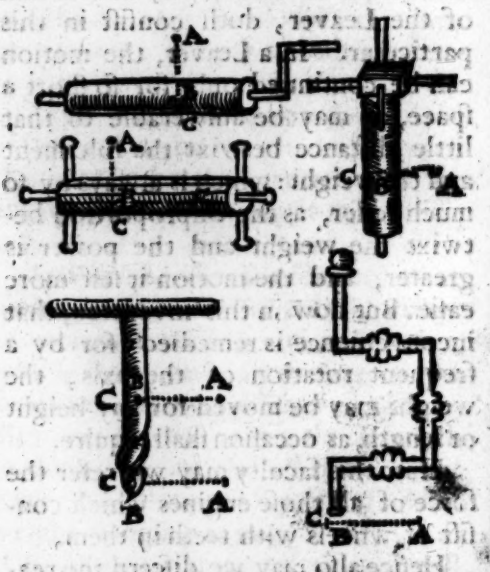
And ſo likewiſe is it for the other ſpokes or handles *E F G H*, at either of which, if we conceive any power, which ſhall move according to the ſame circumference wherein theſe handles are placed, then the ſtrength of this power will be all one, as if it were at *C*. But now ſuppoſing a dead weight hanging at any of them, (as at *E*,) then the diſproportion will vary. The power being ſo much leſs than that at *C*, by how much the line *A C*, is longer then *A I*. The weight *K*, being of the ſame force at *E*, as if it were hung at *I*, in which point the perpendicular of its gravity doth cut the Diameter.

The chief advantage which this in-

inſtrument doth beſtow, above that of the Leaver, doth conſiſt in this particular. In a Leaver, the motion can be continued only for ſo ſhort a ſpace, as may be anſwerable to that little diſtance betwixt the fulciment and the weight: which is always by ſo much leſſer, as the diſproportion betwixt the weight and the power is greater, and the motion it ſelf more eaſie: But now in this invention, that inconvenience is remedied; for by a frequent rotation of the axis, the weight may be moved for any height or length, as occaſion ſhall require.

Unto this faculty may we refer the force of all thoſe engines which conſiſt of wheels with teeth in them.

Hence alſo may we diſcern the reaſon why ſundry inſtruments in common uſe, are framed after the like form with the following figures.

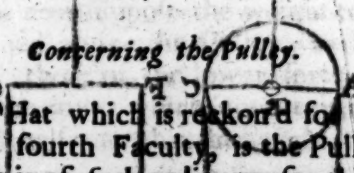


All which are but ſeveral kinds of this third Mechanical faculty. In which the points *A B C*, do repreſent the places of the power, the fulciment, and the weight. The power being in the ſame proportion unto the weight, as *B C* is unto *B A*.

CAP.

CAP. VII.

Concerning the Pulley.



THat which is reckoned for the fourth Faculty, is the Pulley: which is of such ordinary use, that it needs not any particular description. The chief parts of it are divers little rundles, that are movable about their proper axes. These are usually divided according to their several situations, into the upper and lower. If an engine have two of these rundles above, and two below, it is usually called δίτροχος, if three τρίτροχος, if many, πολύτροχος. *Arist. Mechan. c. 19.*

The lower Pulleys only do give force to the motion. If we suppose a weight to hang upon any of the upper rundles, it will then require a power, that in it self shall be fully equal for the sustaining of it.

The

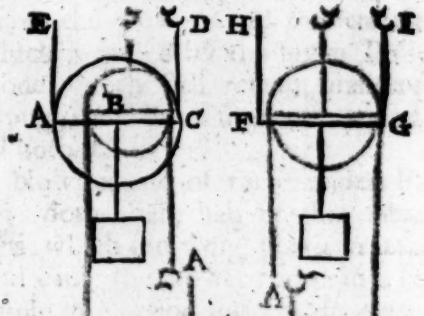
The Diameter *A C*, being as the beam of a ballance, of which *B* is the prop or center. Now the parts *A*, and *C*, being equally distant from this center, therefore the power at *B*, must be equal to the weight at *D*, it being all one as if the power and the weight were fastned by two several strings at the ends of the ballance *F G*.

Now all the upper Pulleys being of the same nature, it must necessarily follow, that none of them do in themselves conduce to the easing of the power, or lightning the weight, but only for the greater convenien-

cy

cy of the motion, the cords by this means being more eaſily moved than otherwiſe they would.

But now ſuppoſe the weight to be ſuſtained above the Pulley, as it is in all thoſe of the lower ſort; and then the power which ſupports it need be but half as much as the weight it ſelf.

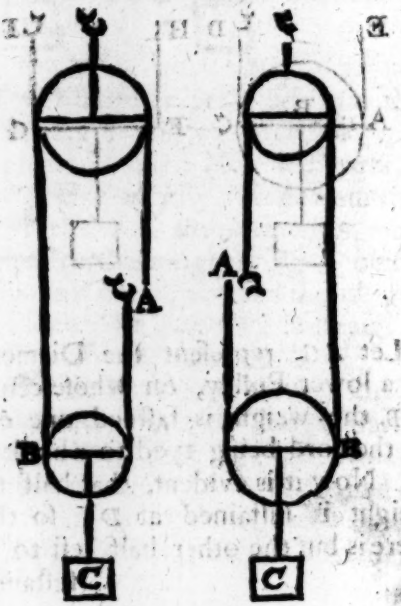


Let *A C*, repreſent the Diameter of a lower Pulley, on whoſe center at *B*. the weight is faſtned, one end of the cord being tyed to a hook at *D*. Now it is evident, that half the weight is ſuſtained at *D*, ſo that there is but the other half left to be

ſuſtained

ſuſtained by the power at *E*. It being all one as if the weight were tyed unto the middle of the ballance *F G*, whoſe ends were upheld by two ſeveral ſtrings, *F H*, and *G I*.

And this ſame ſubduple proportion will ſtill remain, though we ſuppoſe an upper Pulley joyned to the lower, as in theſe two other figures.



Where the power at *A*, is equal to the weight at *B*: Now the weight at *B*, being but half the ponderosity *C*, therefore the power at *A*, notwithstanding the addition of the upper rundle, must be equivalent to half the weight; and as the upper Pulley alone doth not abate any thing of the weight, so neither being joined with the lower, and the same subduple difference betwixt the power and the weight, which is caused by the lower Pulley alone, doth still remain unaltered, though there be an upper Pulley added unto it.

Now as one of these under Pulleys doth abate half of that heaviness which the weight hath in it self, and cause the power to be in a subduple proportion unto it, so two of them do abate half of that which remains, and cause a subquadruple proportion, betwixt the weight and the power; three of them a subsextuple, four a suboctuple: and so for five, or six, or as many as shall be required, they will all of them diminish the

the weight according to this proportion.

Suppose the weight in it self to be 1200 pound, the applying unto it one of these lower Pulleys, will make it but as 600, two of them as 300, three of them as 150, &c.

But now, if we conceive the first part of the string to be fastened unto the lower Pulley, as in this other figure at *F*;

then

that the power at A, will be in a subtriple proportion to the weight E, because the heavines would be then equally divided unto the three points of the lower Diameter B, C, D, each

of them ſupporting a like ſhare of the burden. If unto this lower Pulley there were added another, then the power would be unto the weight in a ſubquintuple proportion. If a third, a ſubſeptuple, and ſo of the reſt. For we muſt note, that the cords in this inſtrument are as ſo many powers, and the rundles as ſo many leavers, or ballances.

Hence it is eaſie to conceive, how the ſtrength of the power may be proportioned according to any ſuch degree, as ſhall be required; and how any weight given, may be moved by any power given.

'Tis not materiall to the force of this inſtrument, whether the rundles of it be big or little, if they be made equal to one another in their ſeveral orders; But it is moſt convenient, that the upper ſhould each of them increaſe as they are higher, and the other as they are lower, because by this means the cords will be kept from tangling.

These Pulleys may be multiplied ac-

according to ſundry different ſituations, not only when they are ſubordinate, as in the former examples, but alſo when they are placed collaterally.

From the former grounds it is eaſie to contrive a ladder, by which a man may pull himſelf up unto any height. For the performance of this, there is required only an upper and a lower rundle:

To the uppermoſt of theſe at *A*, there ſhould be faſtned a ſharp graple or cramp of iron, which may be apt to take hold of any place where it lights. This part being firſt caſt up and faſtned, and the ſtaff *DE*, at the nether end, being put betwixt the legs, ſo that a man may ſit upon the other *BC*, and take hold of the cord at *F*, it is evident that the weight of the perſon at *E*, will be but equal to half ſo much ſtrength at *B*, ſo that a man may eaſily pull himſelf up to the place required, by leaning but little more than half of his own weight on the ſtring *F*. Or if the Pulleys be multiplyed, this experiment may then be wrought with leſs labour.

CAP. VIII.

Of the Wedge.

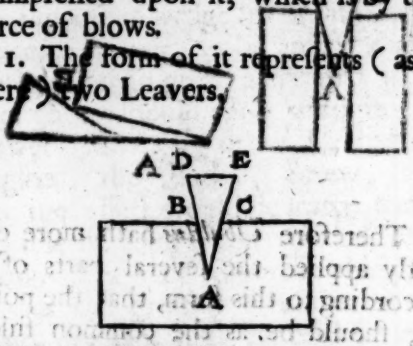
THE fift Mechanical faculty is the Wedge, which is a known inſtrument, commonly uſed in the cleaving

ving of wood. The efficacy and great ſtrength of it may be reſolved unto theſe two particulars:

1. The form of it.

2. The manner whereby the power is impreſſed upon it, which is by the force of blows.

1. The form of it repreſents (as it were) two Leavers.



Each ſide *AD*, and *AE*, being one, the points *B C*, being inſtead of ſeveral props or fulciments; the weight to be moved, at *A*, and the power that ſhould move it, being applyed to the top *D E*, by the force of ſome ſtroak or blow, as *Ariſtotle* hath explained the ſeveral parts of this faculty. But now, becauſe this inſtrument may be ſo uſed that the *Mechan. c.* 8.

point of it ſhall not touch the body to be moved, as in theſe other figures:

Therefore *Ubaldus* hath more exactly applied the ſeveral parts of it according to this form, that the point *A*, ſhould be as the common fulciment, in which both the ſides do meet, and (as it were) uphold one another; the points *B*, and *C*, repreſenting that part of the Leavers where the weight is placed.

It is a general rule, that the more acute the angles of theſe wedges are, by ſo much more eaſie will their motion be; the force being more eaſily impreſſed, and the ſpace wherein the body is moved, being ſo much the leſs.

The

The ſecond particular whereby this faculty hath its force, is the *manner* whereby the power is impreſt upon it, which is by a ſtroke or blow; the efficacy of which doth much exceed any other ſtrength. For though we ſuppoſe a wedge being laid on a peice of timber, to be preſſed down with never ſo great a weight; nay, though we ſhould apply unto it the power of thoſe other Mechanical engines, the Pulley, Screw, &c. yet the effect would be ſcarce conſiderable in compariſon to that of a blow. The true reaſon of which, is one of the greateſt ſubtilties in nature; nor is it fully rendred by any of thoſe who have undertaken the reſolution of it. *Ariſtotle*, *Cardan*, and *Scaliger*, do generally aſcribe it unto the ſwiftneſs of that motion; But there ſeems to be ſomething more in the matter than ſo; for otherwiſe it would follow that the quick ſtroak of a light hammer, ſhould be of greater efficacy, than any ſofter and more gentle ſtriking of a great

* *Mecan. c.* 13. *Subtil. l.* 17 *Exercit.* 331.

ſledge. Or according to this, how ſhould it come to paſs, that the force of an arrow or bullet diſcharged near at hand (when the impreſſion of that violence, whereby they are carried, is moſt freſh, and ſo in probability the motion at its ſwifteſt) is yet notwithſtanding much leſs than it would be at a greater diſtance? There is therefore further conſiderable, the quality of that inſtrument by which this motion is given, and alſo the convenience of diſtance through which it paſſes.

Unto this faculty is uſually reduced the force of files, ſaws, hatchets, &c. which are as it were but ſo many wedges faſtned unto a Vectis or Leaver.

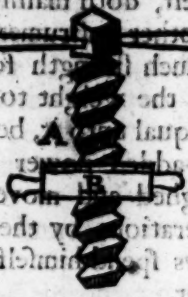
CAP. IX.

Of the Screw.

THat which is uſually recited for the ſixth and laſt Mechanick faculty, is the Screw, which is deſcribed to be a kind of wedge that is multiplied

plied, or continued by a helical revolution about a Cylinder, receiving its motion not from any ſtroak, but from a Vectis at one end of it. It is uſually diſtinguiſhed into two ſeveral kinds: the male, which is meant in the former deſcription; and the female, which is of a concave ſuperficies.

Pappus: Collect. Mathemat. lib. 8.



The former is noted in the figure with the letter *A*, the other with *B*. *Ariſtotle* himſelf doth not ſo much as mention this inſtrument, which yet notwithſtanding is of greater force and ſubtilty, than any of the reſt. It is chiefly applied to the ſqueezing or preſſing of things downwards,

wards, as in the presses for Printing, for wine, oyl, and extracting the juice from other fruits. In the performance of which, the strength of one man may be of greater force, than the weight of a heavy mountain: It is likewise used for the elevating or lifting up of weights.

The advantage of this faculty above the rest, doth mainly consist in this: the other instruments doe require so much strength for the supporting of the weight to be moved, as may be equal unto it, besides that other super-added power whereby it is out-weighed and moved; so that in the operations by these, a man does always spend himself in a continued labour.

Thus (for example) a weight that is lifted up by a Wheel or Pulley, will of it self descend, if there be not an equal power to sustain it. But now in the composure of a Screw, this inconvenience is perfectly remedied; for so much force as is communicated unto this faculty, from the power

power that is applied unto it, is ſtill retained by the very frame and nature of the inſtrument it ſelf, ſince the motion of it cannot poſſibly return, but from the very ſame place where it firſt began. Whence it comes to paſs, that any weight lifted up, with the aſſiſtance of this engine, may likewiſe be ſuſtained by it, without the help of any external power, and cannot again deſcend unto its former place, unleſs the handle of the Screw (where the motion firſt began) be turned back: ſo that all the ſtrength of the power, may be imployed in the motion of the weight, and none ſpent in the ſuſtaining of it.

The chief inconvenience of this inſtrument is, that in a ſhort ſpace it will be ſcrewed unto its full length, and then it cannot be of any further uſe for the continuance of the motion, unleſs it be returned back, and undone again as at the firſt. But this is uſually remedied by another invention, commonly ſtyled a *perpetual*

tual ſcrew, which hath the *motion* of a *wheel*, and the *force* of a *ſcrew*, being both infinite.

For the compoſure of which, inſtead of the female, or concave ſcrew, there muſt be a little wheel, with ſome notches in it, equivalent to teeth, by which the other may take hold of it, and turn it round, as in theſe other figures.

It is uſed in ſome Watches.

This latter engine does ſo far exceed all other contrivances to this purpoſe, that it may juſtly ſeem a wonder why it is not of as common

uſe

use in these times and places, as any of the rest.

CAP. X.

An enquiry into the magnificent works of the Ancients, which much exceeding our later times, may seem to infer a decay in these Mechanical Arts.

THus have I briefly treated concerning the general principles of Mechanicks, together with the distinct proportions betwixt the weight and the power in each several faculty of it. Whence it is easie to conceive the truth and ground of those famous ancient monuments, which seem almost incredible to these following ages. And because many of them recorded by Antiquity were of such vast labour and magnificence, and so mightily disproportionable to humane strength, it shall not therefore be impertinent unto the purpose I aim at, for to specifie some

of

of the most remarkable amongst them, and to enquire into the means and occasion upon which they were first attempted.

Amongst the *Ægyptians*, we read of divers Pyramids, of so vast a magnitude, as time it self in the space of so many hundred years hath not yet devoured. *Herodotus* mentions one of them, erected by *Cleopes* an Ægyptian King, wherein there was not any one stone less than 30 foot long, all of them being fetched from *Arabia*. And not much after, the same Author relates, how *Amasis* another Ægyptian, made himself a house of one entire stone, which was 21 cubits long, 14 broad, and 8 cubits high. The same *Amasis* is reported to have made the statue of a *Sphinx*, or Ægyptian Cat, all of one single stone, whose length was 143 foot, its height 62 foot, the compass of this statues head containing 102 foot. In one of the Ægyptian Temples consecrated to *Jupiter*, there is related to be an Obelisk, consisting of 4 Smaragds

L. 2. c. 175

Plin. l. 36. c. 12.

Plin. l. 37. cap. 5.

or Emeralds; the whole is 40 cubits high, 4 cubits broad at the bottom, and two at the top. *Sesostris* the King of *Ægypt* in a temple at *Memphis*, dedicated to *Vulcan*, is reported to have erected two statues, one for himself, the other for his wife, both consisting of two several stones, each of which were 30 cubits high. *Diodor Sic. cul. Bibliot. lib. 1. Sect. 2.*

Amongst the Jews we read in sacred Writ of *Solomons* Temple, which for its state and magnificence might have been justly reckoned amongst the other wonders of the world, wherein besides the great riches of the materials, there were works too of as great labour. Pillars of brass 18 cubits high, and 12 cubits round; great and costly stones for the foundation of it; *Josephus* tells us, that some of them were 40 cubits, others 45 cubits long. And in the same Chapter he mentions the three famous Towers built by *Herod*, wherein every stone being of white marble, was 20 cubits long, 10 broad, and 5 high. And which was the greatest won- *1 Kings 2. 27. cap. 5. v. 27. De bello Jud. l. 6. c. 6.*

wonder, the old wall it ſelf was ſituated on a ſteep riſing ground, and yet the hills upon it, on the tops of which theſe Towers were placed, were about 30 cubits high, that is ſcarce imaginable by what ſtrength ſo many ſtones of ſuch great magnitude ſhould be conveyed to ſo high a place.

Plin. l. 36. c. 14. Paucivoll. Deperd. Tit. 32. Amongſt the *Grecians* we read of the *Epheſian* Temple dedicated to *Diana*, wherein there were 127 columns made of ſo many ſeveral ſtones, each of them 60 foot high, being all taken out of the quarries in *Aſia*. 'Tis ſtoried alſo of the brazen *Coloſſus*, or great Statue in the Iſland of *Rhodes*, that it was 70 cubits high. The thumbs of it being ſo big that no man could graſp one of them about with both his arms; when it ſtood upright, a ſhip might have paſſed betwixt the legs of it, with all its ſails fully diſplayed: being thrown down by an earthquake, the braſs of it did load 900 Camels. But above all ancient deſigns to this purpoſe, that would have been moſt

wonder-

wonderful, which a Grecian Architect did propound unto *Alexander*, to cut the Mountain *Athos* into the form of a statue, which in his right hand should hold a Town capable of ten thousand men, and in his left a Vessel to receive all the water that flowed from the several springs in the Mountain. But whether *Alexander* in his ambition did fear that such an Idol should have more honour than he himself, or whether in his good husbandry, he thought that such a *Microcosme* (if I may so style it) would have cost him almost as much as the conquering of this great world, or what ever else was the reason, he refused to attempt it. *Vitruv Archit. l. 2.*

Amongst the *Romans* we read of a brazen *Colossus*, made at the command and charges of *Nero*, which was 120 foot high; *Martial* calls it *Sydereus*, or starry. *Suet. Ner.*

Hic ubi Sydereus proprius videt astra Colossus. And it is storied of *M. Curio*, that he erected two *Theaters* sufficiently *Balcirol. Deperd. Tit. 18.*

ently capacious of people, contrived movable upon certain hinges; Sometimes there were ſeveral plays and ſhows in each of them, neither being any diſturbance to the other; and ſometimes they were both turned about, with the people in them, and the ends meeting together, did make a perfect *Amphitheater*: ſo that the ſpectators which were in either of them, might joyntly behold the ſame ſpectacles.

de. Tit. 31. There were beſides at *Rome* ſundry *Obeliſks*, made of ſo many intire ſtones, ſome of them 40, ſome 80, and others 90 cubits high. The chief of them were brought out of Ægypt, where they were dug out of divers quarries, and being wrought into form, were afterward (not without incredible labour, and infinite charges) conveyed unto *Rome*. In the year 1586, there was erected an old *Obeliſk*, which had been formerly dedicated unto the memory of *Julius Ceſar*. It was one ſolid ſtone, being an Ophite or kind of ſpotted Marble. The height of it was 107 foot, the breadth of it

at the bottome was 12 foot, at the top 8. Its whole weight is reckoned to be 956148 pounds, besides the heavines of all those instruments that were used about it, which (as it is thought) could not amount to less then 1042824 pounds. It was transplaced at the charges of Pope *Sixtus* the fifth, from the left side of the *Vatican*, unto a more eminent place about a hundred foot off, where now it stands. The moving of this *Obelisk* is celebrated by the writings of above 56 several Authors, (saith *Monavthalus*) all of them mentioning it, not without much wonder and praise. Now if it seem so strange and glorious an attempt to move this *Obelisk* for so little a space, what then may we think of the carriage of it out of *Egypt*, and divers other far greater works performed by Antiquity? This may seem to infer, that these Mechanical arts are now lost, and decayed amongst the many other ruins of time; which yet notwithstanding cannot be granted, without much ingrati-

Comment. in Mechan. Arist. c. 19.

tude to those learned men, whose labours in this kind we enjoy, and may justly boast of. And therefore for our better understanding of these particulars, it will not be amiss to enquire both *why*, and *how*, such works should be performed in those former and ruder ages, which *are not*, and (as it should seem) *cannot* be effected in these later and more learned times. In the examination of which, we shall find that it is not the want of, are that disables us for them, since these Mechanical discoveries are altogether as perfect, and (I think) much more exact now, than they were heretofore; but it is, because we have not either the same *motives* to attempt such works, or the same *means* to effect them as the Ancients had.

CAP. XI.

That the Ancients had divers motives and means for such vast magnificent works, which we have not.

THE *motives*, by which they were excited to such magnificent attempts, we may conceive to be chiefly three.

Religion.
Policy.
Ambition.

1. *Religion.* Hence was it that most of these stately buildings were intended for some sacred use, being either Temples or * Tombs, all of them dedicated to some of their Deities. It was an in-bred principle in those ancient Heathen, that they could not chuse but merit very much by being liberal in their outward services. And therefore we read of *Cræsus*, that being overcome in a battel, and taken by *Cyrus*, he did revile the Gods of ingratitude, because they had no better care of him, who had so frequently

* As Pyramids, Obelisks.

Herodot. l. 1.

adored them with coſtly oblations. And as they did conceive themſelves bound to part with their lives in defence of their religion: ſo likewiſe to employ their utmoſt power and eſtate, about any ſuch deſign which might promote or advance it. Whereas now, the generality of men, eſpecially the wiſeſt ſort amongſt them, are in this reſpect of another opinion, counting ſuch great and immenſe labours to be at the beſt but glorious vanities. The Temple of *Solomon* indeed was to be a type, and therefore it was neceſſary that it ſhould be ſo extraordinarily magnificent, otherwiſe perhaps a much cheaper ſtructure might have been as commendable and ſerviceable.

2. *Policy*, that by this means they might find out imployment for the people, who of themſelves being not much civilized, might by idleneſs quickly grow to ſuch a rudeneſs and barbariſm, as not to be bounded within any laws of government. Again, *Plin. l. 6. c. 12.* by this means the riches of the King-

dom

dom did not lye idly in their kings treasuries, but was always in motion, which could not but be a great advantage and improvement to the Common-wealth. And perhaps some of them feared lest if they should leave too much money unto their successors, it might be an occasion to insnare them in such idle and vain courses as would ruin their kingdoms. Whereas in these later ages none of all these politick incitements can be of any force, because now there is imployment enough for all, and money little enough for every one.

3. *Ambition* to be known unto posterity; and hence likewise arose that incredible labour and care they bestowed to leave such monuments behind them, as might **continue for ever*, and make them famous unto all after ages: This was the reason of *Absalom's* pillar spoken of in Scripture, *to keep his name in remembrance.* And doubtless this too was the end which many others of the Ancients have aimed at, in those (as they

* Psal. 49. 11.

2 Sam. 18. 18.

thought) everlasting buildings.

But now these later ages are much more active and stirring: so that every ambitious man may find so much business for the present, that he shall scarce have any leisure to trouble himself about the future. And therefore in all these respects, there is a great disproportion betwixt the incitements of those former and these later times unto such magnificent attempts.

Again, as they differ much in their *motives* unto them, so likewise in the means of effecting them.

There was formerly more leisure and opportunity, both for the great men to undertake such works, and for the people to perfect them. Those past ages were more quiet and peaceable, the Princes rather wanting imployment, than being over-prest with it, and therefore were willing to make choice of such great designs, about which to busie themselves: whereas now the world is grown more politick, and therefore more trouble-

troubleſome, every great man having other private and neceſſary buſineſs about which to imploy both his time and means. And ſo likewiſe for the common people, who then living more wildly without being confined to particular trades and profeſſions, might be more eaſily collected about ſuch famous imployments; whereas now, if a Prince have any occaſion for an Army, it is very hard for him to raiſe ſo great a multitude, as were uſually imployed about theſe magnificent buildings. We read of 360000 men that were buſied for twenty years in making one of the Egyptian Pyramids. And *Herodotus* tells us of 1000000 men who were as long in building another of them. About the carriage of one ſtone for *Amaſis* the diſtance of twenty days journey, there was for three years together imployed 2000 choſen men, Governours, beſides many other under-labourers. 'Twas the opinion of * *Joſephus* and *Nazianzen*, that theſe Pyramids were built by *Joſeph* for granaries againſt the years

Lib. 2.

* *Antiq. l. 2. c. 5.*

years of famine. Others think that the brick made by the children of *Israel*, was imployed about the framing of them, becauſe we read that the Tower of *Babel* did conſiſt of brick or artificial ſtone, *Gen.* 11. 3. And if theſe were the labourers that were buſied about them, 'tis no wonder though they were of ſo vaſt a magnitude; for we read that the children of *Israel* at their coming out of *Egypt*, were numbred to be ſix hundred thouſand, and three thouſand, and five hundred and fifty men, *Numb.* 1. 46. ſo many handfuls of earth would almoſt make a mountain, and therefore we may eaſily believe that ſo great a multitude in ſo long a ſpace as their bondage laſted, for above four hundred years, might well enough accompliſh ſuch vaſt deſigns.

In the building of *Solomons* Temple, there were threeſcore and ten thouſand that bare burdens, and fourſcore thouſand hewers in the mountains, 1 *Kings* 5. 15.

The *Epheſian* Temple was built by all

all *Asia* joyning together, the 127 pillars were made by ſo many Kings according to their ſeveral ſucceſſions; the whole work being not finiſhed under the ſpace of two hundred and fifteen years. Whereas the tranſplacing of that Obelisk at *Rome* by *Sixtus* the fift, (ſpoken of before) was done in ſome few days by five or ſix hundred men; and as the work was much leſs than many other recorded by Antiquity, ſo the means by which it was wrought, was yet far leſs in this reſpect than what is related of them.

2. The abundance of wealth, which was then ingroſſed in the poſſeſſion of ſome few particular perſons, being now diffuſed amongſt a far greater number. There is now a greater equality amongſt mankind, and the flouriſhing of Arts and Sciences hath ſo ſtirred up the ſparks of mens natural nobility, and made them of ſuch active and induſtrious ſpirits, as to free themſelves in a great meaſure from that ſlavery, which thoſe former and

wilder Nations were subjected unto.

In building one of the Pyramids, there was expended for the maintenance of the labourers with Radish and Onyons, no less than eighteen hundred talents, which is reckoned to amount unto 188000 Crowns, or thereabouts. And considering the cheapness of these things in those times and places, so much money might go further than a sum ten times greater could do in the maintenance of so many now.

In *Solomons* Temple we know how the extraordinary riches of that King, the general flourishing of the whole State, and the liberality of the people did jointly concur to the building of the Temple. *Pecuniarum copia & populi largitus, majora dictu conabatur*, (saith *Josephus*). The *Rhodian* Colossus is reported to have cost three hundred talents the making. And so were all those other famous Monuments of proportionable expence.

De bell. Jud. l. 6. cap. 6.

Panteirollus speaking of those Theaters that were erected at the charges of

of some private Roman Citizens, saith thus: *Nostro hoc sæculo vel Rex satis haberet quod ageret ædificio ejusmodi erigendo*; and a little after upon the like occasion, *Res mehercule miraculosa, quæ nostris temporibus vix à potentissimo aliquo rege possit exhiberi.* Deperd. Tit. 18.

3. Add unto the two former considerations that exact *care* and indefatigable *industry*, which they bestowed in the raising of those structures: These being the chief and only designs on which many of them did imploy all their best thoughts and utmost endeavours. *Cleopes* an Egyptian King is reported to have been so desirous to finish one of the Pyramids, that having spent all about it he was worth, or could possibly procure, he was forced at last to prostitute his own daughter for necessary maintenance. And we read of *Ramises* another King of *Egypt*, how that he was so careful to erect an Obelisk, about which he had imployed 20000 men, that when he feared lest through the negligence of the artificers, or weakness of the engine, Plin. l. 36. c. 9.

gine, the ſtone might fall and break, he tyed his own ſon to the top of it, that ſo the care of his ſafety might make the workmen more circumſpect in their buſineſs. And what ſtrange matters may be effected by the meer diligence and labour of great multitudes, we may eaſily deſcern from the wild Indians, who having not the art or advantage of Engines, did yet by their unwearied induſtry remove ſtones of an incredible greatneſs. *Acoſta* relates that he himſelf meaſured one at *Tiaguanaco*, which was thirty eight foot long, eighteen broad, and ſix thick, and he affirms that in their ſtateliſt Edifices, there were many other of much vaſter magnitude.

Hiſtor. Ind. l. 6. c. 14.

From all which conſiderations it may appear, that the ſtrangeneſs of thoſe ancient monuments above any that are now effected, does not neceſſarily infer any defect of art in theſe later ages. And I conceive it were as eaſie to demonſtrate the Mechanical Arts in theſe times to be ſo far beyond the knowledge of former

ages,

ages, that had we but the ſame means as the Ancients had, we might effect far greater matters than any they attempted, and that too in a ſhorter ſpace, and with leſs labour.

CAP. XII.

Concerning the force of the Mechanick faculties, particularly the Ballance and Leaver. How they may be contrived to move the whole world, or any other conceivable weight.

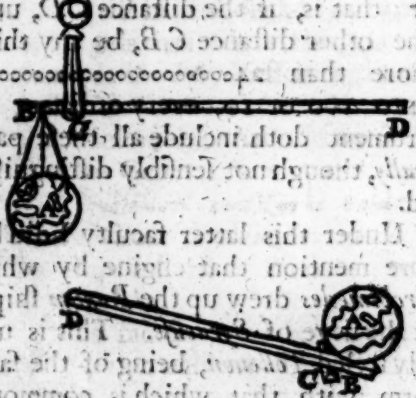
ALL theſe magnificent works of the Ancients before ſpecified, are ſcarce conſiderable in reſpect of art, if we compare them with the famous ſpeeches and acts of *Archimedes*: Of whom it is reported that he was frequently wont to ſay, how that he could move, *Datum pondus cum datâ potentiâ*, the greateſt conceivable weight with the leaſt conceivable power: and that if he did but know where to ſtand and faſten his inſtrument, he could move the world, all this

this great Globe of sea and land; which *premisses*, though they were altogether above the vulgar apprehension or belief, yet because his *acts* were somewhat answerable thereunto, therefore the King of *Syracuse* did enact a law whereby every man was bound to believe what ever *Archimedes* would affirm.

It is easie to demonstrate the Geometrical truth of those strange assertions, by examining them according to each of the forenamed *Mechanick* faculties, every one of which is of infinite power.

To begin with the two first of them, the Ballance and the Leaver, (which I here joyn together, because the proportions of both are wholly alike) 'tis certain, though there should be the greatest imaginable weight, and the least imaginable power, (suppose the whole world, and the strength of one man or infant) yet if we conceive the same disproportion betwixt their several distances in the former faculties from the fulciment or center of gravity,

vity, they would both equiponderate. And if the distance of the power from the center, in comparison to the distance of the weight, were but any thing more than the heaviness of the weight is in respect of the power, it may then be evident from the former principles, that the power would be of greater force than the weight, and consequently able to move it.



Thus if we suppose this great globe at *A*, to con-

contain 24000000000000000000000000 pounds, allowing a hundred pound for each cubical foot in it, (as *Stevinius* hath calculated) yet a man or child at *D*, whose ſtrength perhaps is but equivalent to one hundred, or ten pounds weight, may be able to out-weigh and move it, if there be but a little greater diſpropotion betwixt the two diſtances *C D*, and *C B*, than there is betwixt the heavineſs of the weight, and the ſtrength of the power; that is, if the diſtance *C D*, unto the other diſtance *C B*, be any thing more than 24000000000000000000000000 unto 100 or 10, every ordinary inſtrument doth include all theſe parts *really*, though not ſenſibly diſtinguiſhed.

Static. l. 3. prop. 20.

Under this latter faculty I did before mention that engine by which *Archimedes* drew up the *Roman* ſhips, at the ſiege of *Syracuſe*. This is uſually ſtyled *Tollenon*, being of the ſame form with that which is commonly uſed by Brewers and Dyers, for the drawing of water. It conſiſts of two

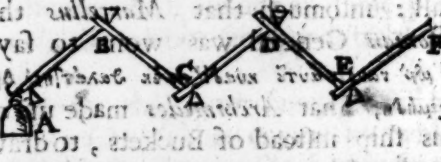
Lipſius Poliorcet. l. 1. Dialog. 6.

poſts

posts, the one fastned perpendicularly in the ground, the other being jointed on cross to the top of it. At the end he fastned a strong hook or grapple of iron, which being let over the wall to the river, he would thereby take hold of the ships, as they passed under, and afterwards by applying some weight, or perhaps the force of Screws to the other end, he would thereby lift them into the open air, where having swinged them up and down till he had shaked out the men and goods that were in them, he would then dash the Vessels against the rocks, or drown them in their sudden fall: insomuch that *Marcellus* the *Roman* General was wont to say, ἐν μὲν ναυσὶν αὐτοῦ κυαδίζειν ἐκ θαλάττης Ἀρχιμήδη, That *Archimedes* made use of his ships instead of Buckets, to draw water with. *Plutarch.* in his life.

This faculty will be of the same force, not only when it is continued in one, but also when it is multiplied in divers instruments, as may be conceived in this other form, which I

do not mention as if it could be serviceable for any motion (since the space by which the weight would be moved, will be so little as not to fall under sense) but only for the better explication of this Mechanick principle, and for the right understanding of that force arising from multiplication in the other faculties, which do all depend upon this. The Wheel, and Pulley, and Screw, being but as so many Leavers of a circular form and motion, whose strength may therefore be continued to a greater space.



Imagine the weight *A*, to be an hundred thousand pounds, and the distance of that point, wherein every Leaver touches either the weight or one another from the point where they touch the prop, to be but one such

ſuch part, whereof the remainder contains ten, then according to the former grounds 10000 at *B*, will equiponderate to *A*, which is 100000, ſo that the ſecond Leaver hath but 10000 pounds to move. Now becauſe this obſerves the ſame proportions with the other in the diſtances of its ſeveral points, therefore 1000 pounds at *C*, will be of equal weight to the former. And the weight at *C*, being but as a thouſand pound, that which is but as a hundred at *D*, will be anſwerable unto it; and ſo ſtill in the ſame proportion, that which is but 10 at *E*, will be equal to 100 at *D*; and that which is but one pound at *F*, will alſo be equal to ten at *E*. Whence it is manifeſt, that 1 pound at *F*, is equal to 100000 at *A*; and the weight muſt alwayes be diminiſhed in the ſame proportion as ten to one, becauſe in the multiplication of theſe Leavers, the diſtance of the point, where the inſtrument touches the weight, from that where it touches the prop, is but as one ſuch

part whereof the remainder contains ten. But now if we imagine it to be as the thousandth part, then muſt the weight be diminiſhed according to this proportion; and then in the ſame multiplication of Leavers, 1 l. will be equal to 1000 000 000 000 000 pounds: ſo that though we ſuppoſe the weight to be never ſo heavy, yet let the diſproportion of diſtances be greater, or the Leavers more, and any little power may move it.

CAP. XII.

Of the Wheel, by multiplication of which it is eaſie to move any imaginable weight.

THE Wheel or *axis in peritrochio*, was before demonſtrated to be of equivalent force with the former faculties. If we conceive the ſame difference betwixt the Semidiameter of the wheels or ſpokes *A C*, and the Semidiameter of the axis *A B*, as there is betwixt the weight of the world,

See the figure cap 6 p. 38.

and

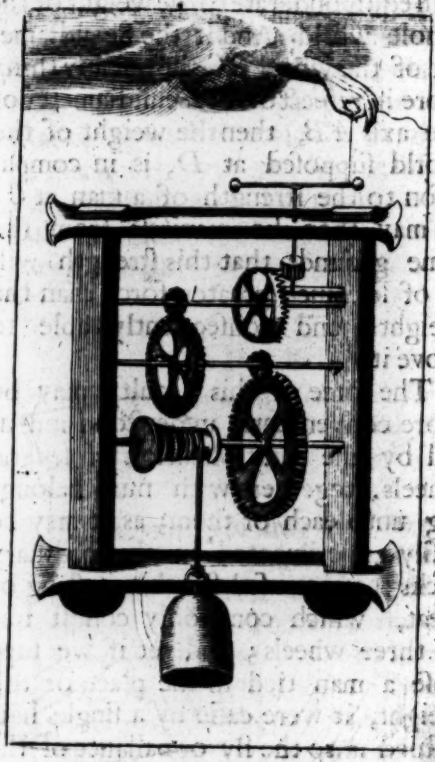
and the ſtrength of a man, it may then be evident, that this ſtrength of one man, by the help of ſuch an inſtrument, will equiponderate to the weight of the whole world. And if the Semidiameter of the wheel *AC*, be but any thing more in reſpect of the Semidiameter of the axis *AB*, then the weight of the world ſuppoſed at *D*, is in compariſon to the ſtrength of a man at *C*; it may then be manifeſt from the ſame grounds that this ſtrength will be of ſo much greater force than the weight; and conſequently able to move it.

The force of this faculty may be more conveniently underſtood and uſed by the multiplication of ſeveral wheels, together with nuts belonging unto each of them; as it may be eaſily experimented in the ordinary Jacks that are uſed for the roaſting of meat, which commonly conſiſt but of three wheels; and yet if we ſuppoſe a man tied in the place of the weight, it were eaſie by a ſingle hair faſtned unto the fly or ballance of the

An engine of many wheels is commonly called *Gloſſocomus*.

How to pull a man above ground with a ſingle hair.

Jack, to draw him up from the ground, as will be evident from this following figure.



Where ſuppoſe the length of the fly or ballance in compariſon to the breadth of its axis, to be as 10 to one, and ſo for the three other wheels in reſpect of the nuts that belong unto them; (though this difference be oftentimes leſs, as we may well allow it to be) withall ſuppoſe the weight (or a man tyed in the place of it) to be a hundred pounds: I ſay, according to this ſuppoſition, it is evident that the power at the ballance, which ſhall be equal to the weight, need be but as 1 to 10000. For the firſt axis is conceived to be but as the tenth part of its wheel, and therefore though the weight in it ſelf be as 10000, yet unto a power that hath this advantage, it is but as 1000, and therefore this thouſand unto the like power at the ſecond wheel, will be but as 100, and this 100 at the third but as 10; and laſtly, this ten at the ballance but as one. But the weight was before ſuppoſed to be 100, which to the firſt wheel will be but 10, to the ſecond as one, to the third as a decimal,

mal, or one tenth, to the ſails as one hundredth part: ſo that if the hair be but ſtrong enough to lift $\frac{1}{10000}$ that is one ten thouſandth part of a man, or (which is all one) one hundreth part of a pound, it may as well ſerve by the help of this inſtrument for the drawing of him up. And though there be not altogether ſo great a diſproportion betwixt the ſeveral parts of a Jack, (as in many perhaps there is not); and though a man may be heavier than is here ſuppoſed, yet 'tis withall conſiderable that the ſtrength of a hair is able to bear much more than the hundredth part of a pound.

Coment. in Gen. c. 1. q. 10. art. 6. De viribus motricibus Theor. 16.

Upon this ground *Merſennus* tells us out of *Solomon de Caus*, that if there were an engine of 12 wheels each of them with teeth, as alſo the axes or nuts that belong unto them, if the Diameter of theſe wheels were unto each *axis*, as a hundred to one: and if we ſuppoſe theſe wheels to be ſo placed, that the teeth of the one might take hold of the axis that belongs unto the next, and that the axis

of

of the handle may turn the first wheel, and the weight be tyed unto the axis of the last, with such an engine as this, saith he, a child (if he could stand anywhere without this earth) might with much ease move it towards him.

For according to the former supposition, that this Globe of sea and land, did contain as many hundred pounds, as it doth cubical feet, *viz.* 24000000000000000000000000, it may be evident that any strength, whose force is but equivalent to 3 pounds, will by such an engine be able to move it.

Of this kind was that engine so highly extolled by *Stevinius*, which he calls *Panceration*, or *Omnipotent*, preferring it before the inventions of *Archimedes*. It consisted of wheels and nuts, as that before specified is supposed. Hither also should be referred the force of racks, which serve for bending of the strongest bows, as also that little pocket-engine wherewith a man may break or wrench open *De Statica prop.*

Remeli. Fig. 160.

pen any doore, together with divers the like instruments in common use.

CAP. XIV.

Concerning the infinite strength of Wheels, Pulleys, and Screws. That it is possible by the multiplication of these, to pull up any Oak by the roots with a hair, lift it up with a straw, or blow it up with ones breath, or to perform the greatest labour with the least power.

FRom what hath been before delivered concerning the nature of the Pulley, it is easie to understand, how this faculty also may be proportioned betwixt any weight, and any power, as being likewise of infinite strength.

'Tis reported of *Archimedes*, that with an engine of Pulleys, to which he applyed only his left hand, he lifted up * 5000 bushels of corn at once, and drew a ship with all its lading

* 7000 saith *Zezes Chiliad.* 2. *Hist.* 35.

ding upon dry land. This engine *Zetzes* calls *Trispatum*, or *Trispastum*, which signifies only a threefold Pulley; But herein he doth evidently mistake; for 'tis not possible that this alone should serve for the motion of so great a weight, because such an engine can but make a subsextuple, or at most a subseptuple proportion betwixt the weight and power, which is much too little to reconcile the strength of a man unto so much heaviness. Therefore *Ubaldus* doth more properly style it *Polyspaston*, or an instrument of many Pulleys: How many, were easie to find out, if we did exactly know the weight of those ancient measures; supposing them to be the same with our bushel in *England*, which contains 84 pints or pounds, the whole would amount to 320000 pounds, half of which would be lightned by the help of one Pulley, three quarters by two Pulleys, and so onward, according to this subduple, subquadruple, and subsextuple proportion: So that if we conceive the strength

Prael. ad Mechan.

of

of the left hand to be equivalent unto 20 or 40 pounds, it is is eaſie to find out how many Pulleys are required to inable it for the motion of ſo great a weight.

Comment. in Gen. c. 1. v. 10. art. 6. Upon this ground *Merſennus* tells us, that any little child with an engine of an hundred double Pulleys, might eaſily move this great Globe of earth, though it were much heavier than it is. And in reference to this kind of engine (ſaith *Monantholius*) are we to underſtand that aſſertion of *Archimedes* (as he more immediately intended it) concerning the poſſibility of moving the world.

Præf. ad Mechan. Ariſtotel.

The Wedg was before demonſtrated to be as a double Vectis or Leaver, and therefore it would be needleſs to explain particularly how this likewiſe may be contrived of infinite force.

The Screw is capable of multiplication, as well as any of the other faculties, and may perhaps be more ſerviceable for ſuch great weights, than any of the reſt. *Archimedes* his engine

engine of greateſt ſtrength, called *Chariſtion*, is by ſome thought to conſiſt of theſe. *Axes habebat cum infinitis cochleis.* And that other engine of his called *Helix* (mentioned by * *Athenæus*) wherewith he lifted *Hiero's* great ſhip into the ſea, without any other help, is moſt likely to be framed of perpetual ſcrews, ſaith *Rivaltus*. *Stevin. de Static. prax.* See *Beſſon.* * *Deipnoſophiſt. l. 5. Oper. exter Archimed.*

Whence it may evidently appear, that each of theſe Mechanick faculties are of infinite power, and may be contrived proportionable unto any conceivable weight. And that no natural ſtrength is any way comparable unto theſe artificial inventions.

'Tis reported of *Sampſon*, that he could carry the gates of a City upon his ſhoulders, and that the ſtrongeſt bonds were unto him but as flax burnt with fire, and yet his hair being ſhaved off, all his ſtrength departed from him. We * read of *Milo*, that he could carry an Oxe upon his back, (and yet when he tried to tear an Oak aſun- *Judg. 15.* * *A. Gel. Noct. Att. l. 15. c. 16.*

der

der that was somewhat riven before, having drawn it to its utmost, it suddenly joyned together again, catching his hands in the cleft, and so strongly manacled him, that he became a prey to the wild beasts.

But now by these Mechanical contrivances, it were easie to have made one of *Sampsons* hairs that was shaved off, to have been of more strength than all of them when they were on. By the help of these arts it is possible (as I shall demonstrate) for any man to lift up the greatest Oak by the roots with a straw, to pull it up with a hair, or to blow it up with his breath.

Suppose the roots of an Oak to extend a thousand foot square, (which is almost a quarter of a mile) and forty foot deep, each cubical foot being a hundred pound weight; which though it be much beyond the extension of any tree, or the weight of the earth, the compass of the roots in the ground (according to common opinion) not extending further than the branches of it in the air, and the

depth

depth of it not above ten foot, beyond which the greateſt rain doth not penetrate (ſaith * *Seneca*). *Ego vinearum diligens foſſor affirmo nullam pluviam eſſe tam magnam, quæ terram ultra decem pedes in altitudinem madefaciat.* And becauſe the root muſt receive its nouriſhment from the help of ſhowers, therefore it is probable that it doth not go below them. So that (I ſay) though the proportions ſuppoſed do much exceed the real truth, yet it is conſiderable that ſome great overplus muſt be allowed for that labour which there will be in the forcible divulſion or ſeparation of the parts of the earth which are continued. * Nat. Qu. l. 3. c. 7.

According to this ſuppoſition, the work of forcing up the Oak by the roots will be equivalent to the lifting up of 400000000 pound weight, which by the advantage of ſuch an engine, as is here deſcribed, may be eaſily performed with the leaſt conceivable power.

The whole force of this engine doth consist in two double Pulleys, twelve wheels, and a sail. One of these Pulleys at the bottome will diminish half of the weight, so that it shall be but as 2000000000; and the other Pulley will abate ¾ three quarters of it: so that it shall be but as 1000000000. And because the beginning of the string being fastned unto the lower Pulley, makes the power to be in a subquintuple proportion unto the weight, therefore a power that shall be as 1000000000, that is, a subquadruple, will be so much stronger than the weight, and consequently able to move it. Now suppose the breadth of all the axes and nuts, to be unto the Diameters of the wheel as ten to one; and it will then be evident, that to a power at the first wheel, the weight is but as 100000000. To the second as 10000000. To the third as 1000000. To the fourth as 100000. To the fifth as 10000, To the sixth as 1000. To the seventh as a 100. To the eighth

See ch. 7.

as 10. To the ninth as 1. To the tenth as $\frac{1}{10}$. one decimal. To the eleventh as $\frac{1}{100}$. To the twelfth as $\frac{1}{1000}$. And the ſails yet leſs. So that if the ſtrength of the ſtraw, or hair, or breath, be but equal to the weight of one thouſandth part of a pound, it may be of ſufficient force to pull up the Oak.

If in this engine we ſuppoſe the diſproportion betwixt the wheels and nuts, to be as an hundred to one, then it is very evident, that the ſame ſtrength of breath, or a hair, or a ſtraw, would be able to move the whole world, as will be eaſily found by calculation. Let this great Globe of ſea and land be imagined (as before) to weigh ſo many hundred pounds as it contains cubical feet; namely, 24000000000000000000000000 pounds. This will be to the firſt Pulley, 120000000000000000000000. To the ſecond leſs than 6000000000000000000000. But for more eaſie and convenient reckoning, let it be ſuppoſed to be ſomewhat more, *viz.* 100000000000000000000. This

This to the first wheel will be but as

	1000000000000000000000.
To the second as	100000000000000000000.
To the third as	10000000000000000000.
To the fourth as	1000000000000000000.
To the fifth	100000000000000.
To the sixth	1000000000000.
To the seventh	10000000000.
To the eighth	100000000.
To the ninth	1000000.
To the tenth	10000.
To the eleventh	100.
To the twelfth	1.
To the sails as	$\frac{1}{100}$.

So that a power which is much less than the hundredth part of a pound, will be able to move the world.

It were needless to set down any particular explication, how such Mechanical strength may be applyed unto all the kinds of local motion; since this, in it self, is so facile and obvious, that every ordinary artificer doth sufficiently understand it.

The Species of local violent motion are by *Aristotle* reckoned to be these four.

Phyſ. l. 7. ſ. 3.

- *Pulſio.*
- *Tractio.*
- *Vectio.*
- *Vertigo.*

Thruſting, Drawing, Carrying, Turning. Unto ſome of which all theſe artificial operations muſt neceſſarily be reduced, the ſtrength of any power being equally appliable unto all of them; So that there is no work impoſſible to theſe contrivances, but there may be as much acted by this art, as can be fancied by imagination.

CAP. XV.

Concerning the proportion of ſlowneſs and ſwiftneſs in Mechanical motions.

HAving already diſcourſed concerning the *ſtrength* of theſe Mechanical Faculties: it remains for the more perfect diſcovery of their natures, that we treat ſomewhat concerning thoſe two differences of artificial motion:

Slow-

Slowneſs,
and
Swiftneſs.

Without the right underſtanding of which, a man ſhall be expoſed to many abſurd miſtakes, in attempting of thoſe things which are either in themſelves impoſſible, or elſe not to be performed with ſuch means as are applyed unto them. I may ſafely affirm, that many, if not moſt miſtakes in theſe Mechanical deſigns, do ariſe from a miſ-apprehenſion of that difference which there will be betwixt the ſlowneſs or ſwiftneſs of the weight and power, in compariſon to the proportion of their ſeveral ſtrengths.

Hence it is, that ſo many engines invented for mines and water-works do ſo often fail in the performance of that for which they were intended, becauſe the artificers many times do forget to allow ſo much time for the working of their engine, as may be proportionable to the difference betwixt the weight and power that

belong unto them; whereas he that rightly underſtands the grounds of this art, may as eaſily find out the difference of ſpace and time, required to the motion of the weight and power, as he may their different ſtrengths; and not only tell how any power may move any weight, but alſo in what a ſpace of *time* it may move any ſpace or *diſtance*.

If it were poſſible to contrive ſuch an invention, whereby any conceivable weight may be moved by any conceivable power, both with the ſame quickneſs and ſpeed (as it is in thoſe things which are immediately ſtirred by the hand, without the help of any other inſtrument) the works of nature would be then too much ſubjected to the power of art: and men might be thereby incouraged (with the builders of *Babel*, or the rebel Gyants) to ſuch bold deſigns as would not become a created being. And therefore the wiſdom of Providence hath ſo confined theſe humane Arts, that what any invention hath

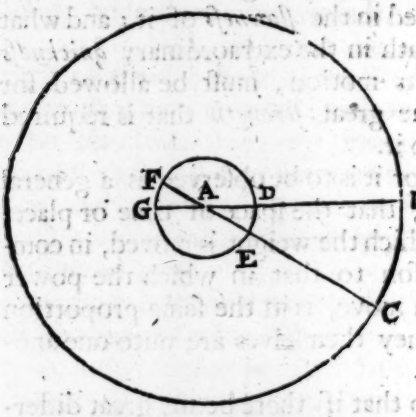
hath in the *ſtrength* of its motion, is abated in the *ſlowneſs* of it; and what it hath in the extraordinary *quickneſs* of its motion, muſt be allowed for in the great *ſtrength* that is required unto it.

For it is to be obſerved as a general rule, that the ſpace of time or place, in which the weight is moved, in compariſon to that in which the power doth move, is in the ſame proportion as they themſelves are unto one another.

So that if there be any great difference betwixt the ſtrength of the weight and the power, the ſame kind of difference will there be in the ſpaces of their motion.

To illuſtrate this by an example:

Let



Let the line *G AB*, repreſent a ballance or leaver, the weight being ſuppoſed at the point *G*, the fulciment at *A*, and the power ſuſtaining the weight at *B*. Suppoſe the point *G*, unto which the weight is faſtned, to be elevated unto *F*, and the oppoſite point *B*, to be depreſſed unto *C*; 'tis evident that the arch *F G*, or (which is all one) *D E*, doth ſhew the ſpace of the weight, and the arch *B C*, the motion of the power. Now both

both theſe arches have the ſame proportion unto one another, as there is betwixt the weight and the power, or (which is all one) as there is betwixt their ſeveral diſtances from the fulciment. Suppoſe *A G*, unto *A B*, to be as one unto four, it may then be evident that *F G*, or *D E*, will be in the ſame proportion unto *B C*. For as any two Semidiameters are unto one another, ſo are the ſeveral circumferences deſcribed by them, as alſo any proportional parts of the ſame circumferences.

And as the weight and power do thus differ in the ſpaces of their motions, ſo likewiſe in the ſlowneſs of it; the one moving the whole diſtance *B C*, in the ſame time, wherein the other paſſes only *G F*. So that the motion of the power from *B* to *C*, is four times ſwifter then that of the weight from *G* to *F*. And thus will it be, if we ſuppoſe the diſproportions to be far greater, whether or no we conceive it, either by a *continuation* of the ſame inſtrument and fa-

faculty, as in the former example, or by a *multiplication* of divers, as in Pulleys, Wheels, &c. By how much the power is in it ſelf leſs than the weight, by ſo much will the motion of the weight be ſlower than that of the power.

To this purpoſe I ſhall briefly touch at one of the Diagrams expreſſed before in the twelfth Chapter, concerning the multiplication of Leavers.

In which, as each inſtrument doth diminiſh the weight according to a decuple proportion, ſo alſo do they diminiſh the *ſpace* and *ſlowneſs* of its motion. For if we ſhould conceive the firſt Leaver *B*, to be depreſſed unto its loweſt, ſuppoſe ten foot, yet the weight *A*, would not be raiſed

ſed above one foot; but now the ſecond Leaver at its utmoſt could move but a tenth part of the firſt, and the third Leaver but a tenth part of the ſecond, and ſo of the reſt. So that the laſt Leaver *F*, being depreſſed, will paſs a *ſpace* 100000 greater, and by a motion, 100000 ſwifter than the weight at *A*.

Thus are we to conceive of all the other faculties, wherein there is conſtantly the ſame diſproportion betwixt the weight and power, in reſpect of the ſpaces and ſlowneſs of their motions, as there is betwixt their ſeveral gravities. If the power be unto the weight but as one unto a hundred, then the ſpace through which the weight moves, will be a hundred times leſs, and conſequently the motion of the weight a hundred times ſlower than that of the power.

So that it is but a vain and impoſſible fancy for any one to think that he can move a great weight with a little power in a little ſpace; but in all theſe Mechanical attempts, that advantage

vantage which is gotten in the ſtrength of the motion, muſt be ſtill allowed for in the ſlowneſs of it.

Though theſe contrivances do ſo extremely increaſe the power, yet they do proportionably protract the time. That which by ſuch helps one man may do in a hundred days, may be done by the immediate ſtrength of a hundred men in one day.

CAP. XVI.

That it is poſſible to contrive ſuch an artificial motion, as ſhall be of a ſlowneſs proportionable to the ſwiftneſs of the heavens.

IT were a pretty ſubtilty to enquire after, whether or no it be not poſſible to contrive ſuch an artificial motion, that ſhould be in ſuch a proportion ſlow, as the heavens are ſuppoſed to be ſwift.

For the exact reſolution of which, it would be requiſite that we ſhould firſt pitch upon ſome *medium*, or indiffe-

different motion, by the diſtance from which, we may judge of the proportions on either ſide, whether ſlowneſs or ſwiftneſs. Now becauſe there is not any ſuch *natural medium*, which may be abſolutely ſtyled an indifferent motion, but that the ſwiftneſs and ſlowneſs of every thing, is ſtill proportioned either to the quantity of bodies, in which they are, or ſome other particular end for which they are deſigned; therefore we muſt take liberty to ſuppoſe ſuch a motion, and this we may conceive to be about 1000 paces, or a mile in an hour.

The ſtarry heaven, or 8th ſphear is thought to move 42398437 miles in the ſame ſpace: So that if it may be demonſtrated that it is poſſible to contrive ſuch a motion, which going on in a conſtant direct courſe, ſhall paſs but the 42398437 part of a mile in an hour, it will then be evident, that an artificial motion may be ſlow, in the ſame proportion as the heavens are ſwift.

Now

Now it was before manifested that according to the difference betwixt the weight and power, so will the difference be betwixt the slowness or swiftness of their motions; whence it will follow, that in such an engine, wherein the weight shall be 42398437 pounds, and the power that doth equiponderate it, but the 42398437 part of a pound (which is easie to contrive) in this engine the power being supposed to move with such a swiftness, as may be answerable to a mile an hour, the weight will pass but the 42398437 part of a mile in the same space, and so consequently will be proportionably slow unto the swiftness of the Heavens.

Preface to *Euclid.*

It is related by our Country-man *J. Dee*, that he and *Cardan* being both together in their travels, they did see an instrument which was at first sold for 20 talents of gold, wherein there was one wheel, which constantly moving round amongst the rest, did not finish one revolution under the space of seven thousand years.

But

But if we farther consider such an instrument of wheels as was mentioned before in the 14 chapter, with which the whole world might be easily moved, we shall then find that the motion of the weight by that, must be much more slow, than the heavens are swift. For though we suppose (saith *Stevinus*) the handle of such an engine with 12 wheels to be turned about 4000 times in an hour, (which is as often as a mans pulse doth beat) yet in ten years space the weight by this would not be moved above $\frac{1}{4}\frac{1}{4}\frac{1}{4}$ 000000000000000 parts of one foot, which is nothing near so much as a hairs breadth. And it could not pass an inch in 1000000 years, saith *Mersennus*.

De stat. pract.

Phænom. Mechan. prop. 11.

The truth of which we may more easily conceive, if we consider the frame and manner of this 12 wheel'd engine. Suppose that in each axis or nut, there were ten teeth, and on each wheel a thousand: then the sails of this engine must be turned a hundred times, before the first wheel (reckon-

ing downward) could be moved round once, and ten thousand times before the second wheel can finish one revolution, and so through the 12 wheels, according to this multiplyed proportion.

So that besides the wonder which there is in the force of these Mechanical motions, the extreme slowness of them is no less admirable; If a man consider that a body would remain in such a constant direct motion, that there could not be one minute of time wherein it did not rid some space, and pass on further, and yet that this body in many years together should not move so far as a hairs breadth.

Which notwithstanding may evidently appear from the former instance. For since it is a natural principle, that there can be no penetration of bodies; and since it is supposed, that each of the parts in this engine do touch one another in their superficies, therefore it must necessarily follow, that the weight does begin and

and continue to move with the power: and (however it is insensible) yet it is certain there must be such a motion so extremely slow, as is here specified. So full is this art of rare and incredible subtilties.

I know it is the assertion of *Cardan, Motus valde tardi, necessario quietes habent intermedias.* Extreme slow motions have necessarily some intermeditate stops and rests: But this is only said, not proved; and he speaks it from sensible experiments, which in this case are fallible. Our senses being very incompetent judges of the several proportions, whether greatness or littleness, slowness or swiftness, which there may be amongst things in nature. For ought we know, there may be some *Organical* bodies, as much less than ours, as the earth is bigger. We see what strange discoveries of extreme minute bodies, (as lice, wheel-worms, mites, and the like) are made by the *Microscope*, wherein their several parts (which are altogether invisible to the

De varietate rerum, l. 9. c. 47.

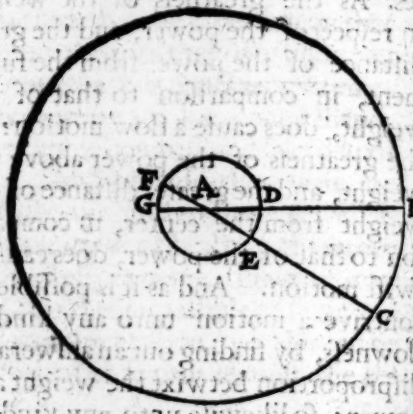
bare eye) will distinctly appear: and perhaps there may be other insects that live upon them as they do upon us. 'Tis certain that our senses are extremely disproportioned for comprehending the whole compass and latitude of things. And because there may be such difference in the *motion* as well as in the *magnitude* of bodies; therefore though such extreme slowness may seem altogether impossible to sense and common apprehension, yet this can be no sufficient argument against the reality of it.

CAP. XVII.

Of swiftness, how it may be increased to any kind of proportion. Concerning the great force of Archimedes *his Engines. Of the Ballista.*

BY that which hath been already explained concerning the slowness of motion, we may the better understand the nature of swiftness, both of them (as is the nature of opposites,

ſites) being produced by contrary cauſes. As the greatneſs of the weight in reſpect of the power, and the great diſtance of the power from the fulciment, in compariſon to that of the weight, does cauſe a ſlow motion: So the greatneſs of the power above the weight, and the greater diſtance of the weight from the center, in compariſon to that of the power, does cauſe a ſwift motion. And as it is poſſible to contrive a motion unto any kind of ſlowneſs, by finding out an anſwerable diſproportion betwixt the weight and power: ſo likewiſe unto any kind of ſwiftneſs. For ſo much as the weight does exceed the power, by ſo much will the motion of the weight be ſlower; and ſo much as the power does exceed the weight, by ſo much will the motion of the weight be ſwifter.



In the Diagram ſet down before, if we ſuppoſe *F* to be the place of the power, and *C* of the weight, the point *A* being the fulciment or center, then in the ſame ſpace of time, wherein the power does move from *F* to *G*, the weight will paſs from *C* to *B*. Theſe diſtances having the ſame diſproportion unto one another, as there is betwixt *A F*, and *A C*, which is ſuppoſed to be quadruple. So that in this example, the weight will move four

four times swifter than the power. And according as the power does exceed the weight in any greater disproportion, so will the swiftness of the weight be augmented.

Hence may we conceive the reason of that great force which there is in Slings, which have so much a greater swiftness, than a stone thrown from the hand, by how much the end of the Sling is farther off from the shoulder-joynt, which is the center of motion. The Sacred history concerning *Davids* victory over *Goliah*, may sufficiently evidence the force of these. *Vegetius* relates that it was usual this way to strike a man dead, and beat the soul out of his body, without so much as breaking his armour, or fetching blood. *Membris integris lethale tamen vulnus important, & sine invidia sanguinis, hostis lapidis ictu intereat.*

1 Sam. 17. 49. *Lipsius Polior. l. 4. Dialog. 2.*

In the use of these, many of the Ancients have been of very exquisite and admirable skill. We read of *seven hundred Benjamites left-handsd, that could*

Judges 20. 16.

sling a stone at a hairs breadth, and not miss. And there is the like storied of a whole Nation amongst the Indians, who from their excellency in this art were stiled *Baleares.* They were so strict in teaching this art unto their young ones, *Ut cibum puer à matre non accipit, nisi quem ipsâ monstrante percussit.* That the mother would not give any meat to her child, till (being set at some distance) he could hit it with slinging.

Ἀπὸ τοῦ βάλλειν. Diodor. Sicul. Biblioth. l. 5. L. Florus Hist. l. 3. cap. 8. Jo. Boemus Aubanus de moribus gentium. l. 3. c. 26.

For the farther illustration of this subject, concerning the *swiftness* of motion, I shall briefly specifie some particulars concerning the engines of War used by the Ancients. Amongst these, the most famous and admirable were those invented by *Archimedes*, by which he did perform such strange exploits, as (were they not related by so many and such judicious Authors) would scarce seem credible even to these more learned ages. The acts of that famous Engineer, are largely set down by [a] *Polybius*, [b] *Tzetzes*, [c] *Proclus*, [d] *Plutarch*, [e] *Li-*

a Histo. l. 4. b Histor. Chilias 2. histor. 35. c Li. 2. c. 3. d Marcellus. e Histor. l. 24.

vy, and divers others. From the first of whom alone, we may have sufficient evidence for the truth of those relations. For besides that he is an Author noted to be very grave and serious in his discourses, and does solemnly promise in one place that he will relate nothing but what either he himself was an eye-witness of, or else what he had received from those that were so; I say, besides all this, it is considerable, that he himself was born not above thirty years after the siege of *Syracuse*. And afterwards having occasion to tarry some weeks in that City, when he travelled with *Scipio*, he might there perhaps see those engines himself, or at least take his information from such as were eye-witnesses of their force: So that there can be no colourable pretence for any one to distrust the particulars related of them.

Polyb. l. 4. juxta initium.

In brief, the sum of their reports is this: When the *Roman* forces under the conduct of *Marcellus*, had laid siege unto that famous City, (of which

which both by their former successes, and their present strength, they could not chuse but promise themselves a speedy victory); yet the arts of this one Mathematician, notwithstanding all their policies and resolutions, did still beat them back to their great disadvantage. Whether they were near the wall or farther from it, they were still exposed to the force of his engines, καὶ μακρὰν ἀφεστῶτας καὶ συνεγγὺς ὄντας, οὐ μόνον ἀπράκτους παρεσκάζε πρὸς τὰς ἰδίας ἐπιβολὰς, ἀλλὰ καὶ διέφθειρε τοὺς πλείστους αὐτῶν. From the multitude of those stones and arrows, which he shot against them, was he styled ἑκατόγχειρ, or *Briareus*. Those defensive engines that were made by the *Romans* in the form of Penthouses for to cover the assailants from the weapons of the besieged, these would he presently batter in pieces with great stones and blocks. Those high towers erected in some of the ships, out of which the *Romans* might more conveniently fight with the defendants on the wall, these also were so

Cæl. Rhod. Ant. lect. l. 2. c. 16. Plutem Testudo.

so broken by his engines, that no Cannon or other instrument of Gunpowder, (saith a learned man,) had they been then in use, could have done greater mischief. In brief, he did so molest them with his frequent and prodigious batteries, that the common soldiers were utterly discouraged from any hopes of success. *Sir Walt. Raleigh Hist. l. 5. c. 3 sect. 16.*

What was the particular frame and manner of these engines, cannot certainly be determined; but to contrive such as may perform the like strange effects, were not very difficult to any one who is throughly versed in the grounds of this art. Though perhaps those of *Archimedes* in respect of divers circumstances, were much more exact and proper for the purposes to which they were intended, than the invention of others could be; He himself being so extraordinarily subtil and ingenious above the common sort of men.

'Tis probable that the general kind of these engines, were the same with those that were used afterwards

wards amongst the *Romans* and other Nations. These were commonly divided into two sorts: styled

Ballistæ.
Catapultæ.

Both which names are sometimes used promiscuously; but according to their propriety † *Ballista* does signifie an engine for the shooting of stones, and *Catapulta* for darts or arrows.

Vid. Naudæum de Stud. Militar. l. 2

† ἀπὸ τοῦ βάλλειν, called also λιθόβολος. πετρόβολος. *Fundibalus. Petraria.*

The former of these was fitted either to carry divers lesser stones, or else one greatest one. Some of these engines made for great stones, have been proportioned to so vast and immense a weight, as may seem almost incredible: which occasioned that in *Lucan.*

At saxum quoties ingenti verberis ictu
Excutitur, qualis rupes quam vertice montis
Abscidit impulsu ventorum adjuta vetustas,
Frangit cuncta rumes; nec tantum corpora pressa
Exanimat, totos cum sanguine dissipat artus.

Lib. 3.

With these, they could easily batter down the walls and Towers of any Fort, So *Ovid.*

Quam

Quam grave balliſtæ machina pulſat onus!

And *Statius* — *Quæ turbine bellica quondam*
Librati ſaliunt pantarum in clauſtra molares.

The ſtones that were caſt from theſe, were of any form, *Enormes & ſepulchrales*, Milſtones or Tomb-ſtones. Sometimes for the farther annoyance and terror of any beſieged place, they would by theſe throw into it dead bodies, either of men or horſes, and ſometimes only parts of them, as mens heads. *Lipſius Poliorcet. l. 3. Dial. 3.*

Athenæus mentions one of theſe *Balliſtæ* that was proportiond unto a ſtone of three talents weight, each talent being 120 pounds (ſaith *Vitruvius*) ſo that the whole will amount to 360 pounds. But it is ſtoried of *Archimedes*, that he caſt a ſtone into one of *Marcellus* his ſhips, which was found to weigh ten talents. There is ſome difference amongſt * Authors, concerning what kind of talent this ſhould be underſtood, but it is certain that *Ext-* *Deipnoſoph. l. 5.* *Archit. l. 10. c. ult.* λίθον δεκατάλαντον. *Plut. Marcell.* * *Dav. Rivaltus Comen in Archim. Oper.*

that in *Plutarchs* time, (from whom we have this relation) one talent did amount to 120 pounds (ſaith *Suidas*): according to which account, the ſtone it ſelf was of no leſs than twelve hundred pound weight. A weapon (one would think) big enough for thoſe rebel Gyants that fought againſt the gods. Now the greateſt Cannon in uſe, does not carry above 64 pound weight, which is far ſhort of the ſtrength in theſe Mathematical contrivances. Amongſt the Turks indeed, there have been ſometimes uſed ſuch powder-inſtruments, as may equal the force of thoſe invented by *Archimedes*. *Gab. Naudæus* tells us of one bullet ſhot from them at the ſiege of *Conſtantinople*, which was of above 1200 pound weight; This he affirms from the relation of an Archbiſhop, who was then preſent and did ſee it; the piece could not be drawn by leſs than a hundred and fifty yoak of oxen, which might almoſt have ſerved to draw away the Town it ſelf. But though there hath been perhaps ſome one

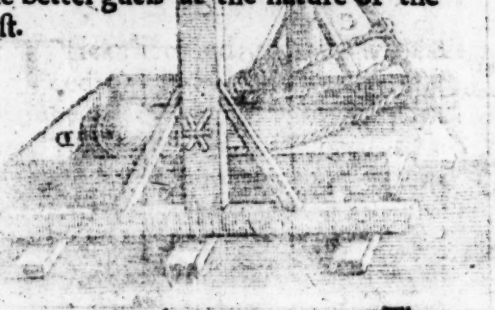
Naudæus de Studio. Milit. l. 2.

De Stud. Mil. l. 2.

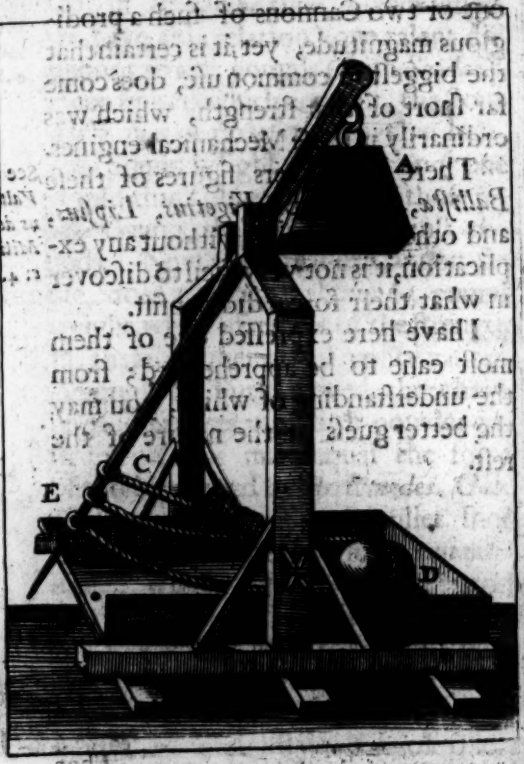
one or two Cannons of such a prodigious magnitude, yet it is certain that the biggest in common use, does come far short of that strength, which was ordinarily in these Mechanical engines.

There are divers figures of these *Ballistæ*, set out by *Vigetius*, *Lipsius*, and others; but being without any explication, it is not very facil to discover in what their forces did consist. See *Rob: Valturius de re Milit. l. 10 c. 4.*

I have here expressed one of them most easie to be apprehended; from the understanding of which, you may the better guess at the nature of the rest.



That



That great box or cavity at *A*, is supposed to be full of some heavy weight, and is forced up by the turning

ning of the axis and spokes *BC*. The stone or bullet to be discharged being in a kind of sling at *D*, which when the greater weight *A*, descends, will be violently whirled upwards, till that end of the sling at *E*, coming to the top, will flye off, and discharge the stone as the skilful Artist should direct it.

CAP. XVIII.

Concerning the Catapultæ, or Engines for Arrows.

The other kind of engine was called *Catapultæ*, διὰ τὴν πέλτης, which signifies a spear or dart, because it was used for the shooting of such weapons: some of these were proportioned unto spears of twelve cubits long; they did carry with so great a force, *ut interdum nimio ardore scintillant*, (saith *Ammianus*) that the weapons discharged from them were sometimes (if you can believe it) set on fire by the swiftness of their motion.

In Greek ἀκταπέλτης. *Athenæus Deipnos. l. 5.*

Lib. 23.

Lipsius Poliorcet. l. 3. Dial. 2.

Diod. Sic. Biblioth. l. 14. Sardus de Invert. Rerum. l. 2.

The first invention of these is commonly ascribed to *Dionysius* the younger, who is said to have made them amongst his other preparations against *Carthage*. But we have good reason to think them of more ancient use, because we read in Scripture that *Uzziah made in Jerusalem engines invented by cunning men to shoot arrows and great stones withall:* though it is likely these inventions were much bettered by the experience of after-ages.

2 Chron. 26. 15.

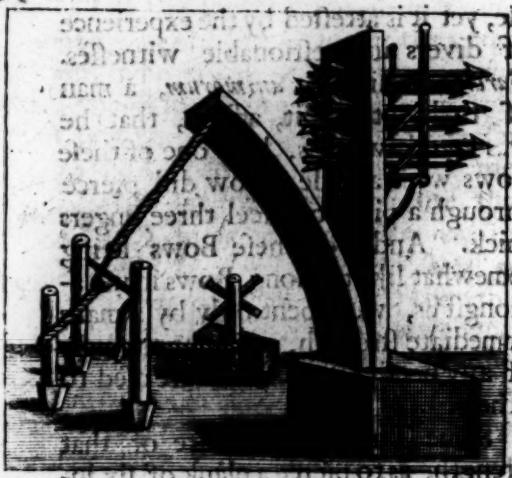
The usual form of these *Catapultæ*, was much after the manner of great Bows placed on Carriages, and wound up by the strength of several persons. And from that great force which we find in lesser Bows, we may easily ghess at the greater power of these other engines. 'Tis related of the Turkish Bow, that it can strike an arrow through a piece of steel or brass two inches thick; and being headed only with word, it pierces Timber of eight inches. Which though it may seem incredi-

Sir Fran. Bacon Nat. Hist. Exp. 704.

ble, yet it is atteſted by the experience of divers unqueſtionable witneſſes. *Barclay* in his *Icon animorum*, a man of ſufficient credit, affirms, that he was an eye-witneſs, how one of theſe Bows with a little arrow did pierce through a piece of ſteel three fingers thick. And yet theſe Bows being ſomewhat like the long Bows in uſe amongſt us, were bent only by a mans immediate ſtrength, without the help of any bender or rack that are uſed to others.

Some Turkiſh Bows are of that ſtrength, as to pierce a plank of ſix inches in thickneſs, (I ſpeak what I have ſeen) ſaith *M. Jo. Greaves* in his *Pyramodographia*. How much greater force then may we conceive to be impreſſed by the *Catapulta*?

Theſe were ſometimes framed for the diſcharging of two or three arrows together, ſo that each of them might be directed unto a ſeveral aim. But it were as eaſie to contrive them after the like manner for the carriage of twenty arrows, or more, as in this figure.



Both these kinds of engines when they were used at the siege of any City, were commonly carried in a great wooden Turret (first invented by * *Demetrius*). It was driven upon four wheels at the bottom, each of its sides being forty five cubits, its height ninety. The whole was divided into nine several partitions, every one of which did contain divers engines for battery: from its use in the battering and taking of Cities it is stiled

* Who was before styled *Poliorcetes*. This kind of Turret was first used at the siege of *Cyprus*, & is thus described by *Diodorus Sicul Bibliotb. l.* 20.

ſtiled by the name of *Helepolis*.

He that would be informed in the nature of Bows, let him conſult *Merſennus De Balliſtica & Aconti ſmologia*, where there are divers ſubtil inquiries and demonſtrations, concerning the ſtrength required to the bending of them to any diſtance. The force they have in the diſcharge according to ſeveral bents, the ſtrength required to be in the ſtring of them, the ſeveral proportions of ſwiftneſs and diſtance in an arrow ſhot vertically, or horizontally, or tranſverſally.

Thoſe ſtrange effects of the Turkiſh Bow (mentioned before) ſo much exceeding the force of others, which yet require far greater ſtrength for the bending of them, may probably be aſcribed either to the natural cauſe of *attraction by ſimilitude of ſubſtance* (as the Lord *Bacon* conjectures); For in theſe experiments the head of the arrow ſhould be of the ſame ſubſtance (whether ſteel or wood) with that which it pierces: Or elſe to that *juſt proportion* betwixt the

weight of the arrow, and the ſtrength of the bow, which muſt needs much conduce to the force of it, and may perhaps be more exactly diſcovered in theſe, then it is commonly in others.

CAP. XIX.

A compariſon betwixt theſe ancient Engines, and the Gun-powder inſtruments now in uſe.

IT ſhall not be altogether impertinent to inquire ſomewhat concerning the advantages and diſadvantages betwixt thoſe Militay offenſive engines, uſed amongſt the Ancients, and thoſe of theſe later ages.

In which inquiry there are two particulars to be chiefly examined:

1. The force of theſe ſeveral contrivances, or the utmoſt that may be done by them.

2. Their price, or the greatneſs of the charges required unto them.

1. As for the force of theſe ancient

ent inventions, it may ſufficiently appear from thoſe many credible relations mentioned before; to which may be added that in *Joſephus*, which he ſets down from his own eye-ſight, being himſelf a chief Captain at the ſiege of *Jotapata*, where theſe events happened. He tells us that beſides the multitude of perſons, who were ſlain by theſe *Roman* Engines, being not able to avoid their force, by reaſon they were placed ſo far off, and out of ſight; beſides this, they did alſo carry ſuch great ſtones, with ſo great a violence, that they did therewith batter down their walls and Towers. A great-bellied woman walking about the City in the day-time, had her child ſtruck out of her womb, and carried half a furlong from her. A ſoldier ſtanding by his Captain *Joſephus*, on the wall, had his head ſtruck off by another ſtone ſent from theſe *Roman* Engines, and his brains carried three furlongs off. *De bello Judaico, l. 3. c. 9.*

To this purpoſe *Cardan* relates out of *Ammianus Marcellinus*, *Tanto impetu* *De variet. l. 12. c. 58.*

impetu sertur lapis ut uno viso lapide quamvis intacti barbari fuerint ab eo, destiterunt à pugna & abierunt. Many foreign people being so amazed at the strange force of these Engines, that they durst not contest with those who were masters of such inventions. 'Tis frequently asserted, that bullets have been melted in the air, by that extremity of violent motion imprest from these slings.

Fundáque contorto transverberat aëra plumbo,
Et mediis liquidæ glandes in nubibus errant.

So *Lucan*, speaking of the same Engines.

Inde faces & saxa volant, spatioque solutæ
Aëris & calidæ liquefactæ pondere glandes.

Which relations, though they may seem somewhat poetical and improbable, yet *Aristotle* himself (*De Cœlo, lib.* 2. *c.* 7.) doth suppose them as unquestionable. From whence it may be inferred, that the force of these Engines

gines does rather exceed than come ſhort of our Gun-powder inventions.

Add to this that opinion of a learned man, (which I cited before) that *Archimedes* in the ſiege of *Syracuſe*, did more michief with his Engines, than could have been wrought by any Cannons, had they been then in uſe. *Sir Walt. Raleigh Hiſt. l. 5. c. 3. Sect. 16. See Lipſius de militiâ Romanâ. l. 5.*

In this perhaps there may be ſome diſadvantage, becauſe theſe Mathematical Engines cannot be ſo eaſily and ſpeedily wound up, and ſo certainly levelled as the other may.

2. As for the price or charges of both theſe, it may be conſidered under three particulars:

1. Their making.
2. Their carriage or conveyance.
3. Their charge and diſcharging.

In all which reſpects, the Cannons now in uſe, are of much greater coſt than theſe other inventions.

1. The making or price of theſe Gun-powder inſtruments is extremely expenſive, as may be eaſily judged by the weight of their materials. A whole

Cannon

Cannon weighing commonly 8000 *l.* a half Cannon 5000, a Culverin 4500, a Demiculverin 3000; which whether it be in iron or brass, must needs be very costly, only for the matter of them; besides the farther charges required for the form and making of them, which in the whole must needs amount to several hundred pounds. Whereas these Mathematical inventions consisting chiefly of Timber, and Cords, may be much more cheaply made; The several degrees of them which shall answer in proportion to the strength of those other, being at the least ten times cheaper; that is, ten Engines that shall be of equal force either to a Cannon or Demicannon, Culverin or Demiculverin, may be framed at the same price that one of these will amount to: So that in this respect there is a great inequality.

2. As for the Carriage or conveyance; a whole Cannon does require at the least 90 men, or 16 horses, for the draught of it; a half Cannon 56 men,

men, or 9 horſes; a Culverin 50, men, or 8 horſes; a Demiculverin 36 men, or 7 horſes; Suppoſing the way to be hard and plain, in which notwithſtanding the motion will be very ſlow. But if the paſſage prove riſing and ſteep, or rotten and dirty, then they will require a much greater ſtrength and charge for the conveyance of them. Whereas theſe other inventions are in themſelves more light (if there be occaſion for the draught of them) being eaſily taken aſunder into ſeverals parts. And beſides their materials are to be found every where, ſo that they need not be carried up and down at all, but may be eaſily made in the place where they are to be uſed.

3. The materials required to the charging of theſe Gun-powder inſtruments are very coſtly. A whole Cannon requiring for every charge 40 pounds of powder, and a bullet of 64 pounds; a half Cannon 18 pounds of powder, and a bullet of 24 pounds; a Culverin 16 pounds of powder, and

a bullet of 19 pounds; a Demiculverin 9 pounds of powder, and a bullet of 12 pounds: whereas those other Engines may be charged only with stones, or (which may serve for terrour) with dead bodies, or any such materials as every place will afford without any cost.

So then, put all these together: If it be so that those ancient inventions did not come short of these other in regard of force, and if they do so much excel them in divers others respects; It should seem then, that they are much more commodious than these latter inventions, and should be preferred before them. But this enquiry cannot be fully determined without particular experience of both.

CAP.

CAP. XX.

That it is possible to contrive such an artificial motion, as may be equally swift with the supposed motion of the heavens.

FOR the conclusion of this Discourse, I shall briefly examine (as before concerning slowness) whether it be possible to contrive such an artificial motion, as may be equal unto the supposed swiftness of the heavens. This question hath been formerly proposed and answered by *Cardan*, where he applies it unto the swiftness of the Moons Orb; but that Orb being the lowest of all, and consequently of a dull and sluggish motion, in comparison to the rest; therefore it will perhaps be more convenient to understand the question concerning the eighth sphere or starry heaven. *De Variet. Rerum l. 9. c. 47.*

For the true resolution of this, it should be first observed, that a material substance is altogether incapable

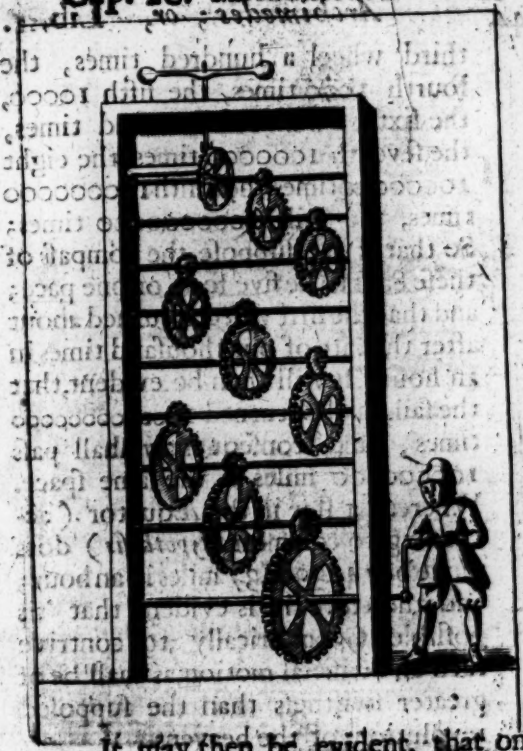
ble of ſo great a celerity, as is uſually aſcribed to the Celeſtiall Orbs, (as I have proved elſewhere). And therefore the quæry is not to be underſtood for any real and experimental, but only notional and Geometrical contrivance.

The earth a Planet, *prop.* 9.

Now that the ſwiftneſs of motion may be thus increaſed, according to any conceivable proportion, will be manifeſt from what hath been formerly delivered concerning the grounds and nature of ſlowneſs and ſwiftneſs. For according as we ſhall ſuppoſe the power to exceed the weight; ſo may the motion of the weight be ſwifter than that of the power.

But to anſwer more particularly: Let us imagine every wheel in this following figure to have an hundred teeth in it, and every nut ten:

It



It may then be evident, that one revolution of the first wheel, will turn the nut, and consequently the second wheel on the same axis ten times, the third

third wheel a hundred times, the fourth 1000 times, the fifth 10000, the sixth a hundred thousand times, the seventh 1000000 times, the eight 10000000 times, the ninth 100000000 times, the Sails 1000000000 times; So that if we suppose the compass of these Sails to be five foot, or one pace; and that the first wheel is turned about after the rate of one thousand times in an hour: It will then be evident, that the sails shall be turned 1000000000000 times, and consequently shall pass 100000000 miles in the same space. Whereas a star in the *Equator* (according to common *Hypotheses*) does move but 42398437 miles in an hour; and therefore it is evident that 'tis possible Geometrically to contrive such an artificial motion, as shall be of greater swiftness than the supposed revolutions of the heavens.

DÆDA-

DÆDALUS:
OR,
Mechanical Motions.

The Second Book.

CHAP. I.

The divers kind of Automata, *or Self-movers. Of Mills, and the contrivance of several motions by rarified air. A brief digression concerning wind-guns*

AMongst the variety of artificial motions, those are of most use and pleasure, in which, by the application of some continued strength, there is bestowed a regular and lasting motion.

These we call the *αὐτόματα*, or *self-movers:* which name in its utmost latitude, is sometimes ascribed unto those motions that are contrived from the strength of living creatures, as Chariots, Carts, &c. But in its strictness and propriety, it is only appliable unto such inventions, wherein the motion is caused either by somthing

that belongs unto its own frame, or else by some external inanimate agent.

Whence these αὐτόματα are easily distinguishable into two sorts:

1. Those that are moved by something which is extrinsecal unto their own frame, as Mills by water or wind.

2. Those that receive their motion from something that does belong to the frame it self, as Clocks, Watches, by weights, springs, or the like.

Of both which sorts there have been many excellent inventions: In the recital of them, I shall insist chiefly o such as are most eminent for their ra ty and subtilty.

Amongst the αὐτόματα that recei their motion from some external agen those of more common use are Mills.

And first, the Water-mills, which are thought to be before the other, though neither the first Author, nor so much as the time wherein they were invented is fully known. And therefore *Polydor Virgil* refers them amongst other fatherless inventions. *Pliny* indeed doth mention them, as being commonly used in his ti me: and yet

De invent. Rerum, l. 3 c. 18.

Nat. Hist. l. 18. c. 10.

others

others affirm, that *Belisarius* in the reign of *Justinian*, did first invent them: Whence *Pancirollus* concludes, that it is likely their use was for some space intermitted, and being afterwards renewed again, they were then thought to be first discovered. *De Repert. Tit. 22.*

However 'tis certain, that this invention hath much abridged and advantaged the labours of men, who [illegible] condemned unto this [illegible] unto the Galleys. And [illegible] waters hath been useful [illegible] may it be contrived [illegible] poses. Herein doth [illegible] ficer chiefly consist, [illegible] of these common [illegible] lous and beneficial [illegible] hem serviceable not [illegible] grinding of corn, but [illegible] ing of iron or other oar, [illegible] king of paper, the elevating of water, or the like. *Ad Pistrinum.*

To this purpose also are the Mills that are driven by wind, which are so much more convenient than the other, by how much their situations

that belongs unto its own frame, or elſe by ſome external inanimate agent.

Whence theſe ἀυτόματα are eaſily diſtinguiſhable into two ſorts:

1. Thoſe that are moved by ſomething which is extrinſecal unto their own frame, as Mills by water or wind.

2. Thoſe that receive their motion from ſomething that does belong to the frame it ſelf, as Clocks, Watches, by weights, ſprings, or the like.

Of both which ſorts there have been many excellent inventions: In the recital of them, I ſhall inſiſt chiefly on ſuch as are moſt eminent for their rarity and ſubtilty.

Amongſt the ἀυτόματα that receive their motion from ſome external agent, thoſe of more common uſe are Mills.

And firſt, the Water-mills, which are thought to be before the other, though neither the firſt Author, nor ſo much as the time wherein they were invented is fully known. And therefore *Polydor Virgil* refers them amongſt other fatherleſs inventions. *Pliny* indeed doth mention them, as being commonly uſed in his ti me: and yet others

De invent. Rerum, l. 3 c. 18.

Nat. Hiſt. l. 18. c. 10.

others affirm, that *Belisarius* in the reign of *Justinian*, did first invent them: Whence *Pancirollus* concludes, that it is likely their use was for some space intermitted, and being afterwards renewed again, they were then thought to be first discovered. *De Repert. Tit. 22.*

However 'tis certain, that this invention hath much abridged and advantaged the labours of men, who were before condemned unto this slavery, as now unto the Galleys. And as the force of waters hath been useful for this, so likewise may it be contrived to divers other purposes. Herein doth the skill of an artificer chiefly consist, in the application of these common motions unto various and beneficial ends, making them serviceable not only for the grinding of corn, but for the preparing of iron or other oar, the making of paper, the elevating of water, or the like. *Ad Pistrinum.*

To this purpose also are the Mills that are driven by wind, which are so much more convenient than the other, by how much their situations

may be more eaſie and common. The motions of theſe may likewiſe be accommodated to as various uſes as the other, there being ſcarce any labour, to the performance of which an ingenious artificer cannot apply them. To the ſawing of Timber, the plowing of land, or any other the like ſervice, which cannot be diſpatched the ordinary way, without much toil and tediouſneſs. And it is a wonderful thing to conſider, how much mens labours might be eaſed and contracted in ſundry particulars, if ſuch as were well skilled in the principles and practiſes of theſe Mechanical experiments, would but thorowly apply their ſtudies unto the inlargement of ſuch inventions.

There are ſome other motions by wind or air, which (though they are not ſo common as the other), yet may prove of excellent curioſity, and ſingular uſe. Such was that muſical inſtrument invented by *Cornelius Dreble*, which being ſet in the ſun-ſhine, would of it ſelf render a ſoft and pleaſant

Marcell. Frankbein. Epiſt. ad Joh. Erneſtum.

pleaſant harmony, but being removed into the ſhade would preſently become ſilent. The reaſon of it was this; the warmth of the ſun, working upon ſome moiſture within it, and rarifying the inward air unto ſo great an extenſion, that it muſt needs ſeek for a vent or iſſue, did thereby give ſeveral motions unto the inſtrument.

Like that ſtatue of *Memnon*, in *Egypt*, which makes a ſtrange noiſe whenever the ſun begins to ſhine upon it. *Tacit. Annal.* 2. *Strabo* affirms that he had both ſeen and heard it.

Somewhat of this nature are the *Eolipiles*, which are concave Veſſels, conſiſting of ſome ſuch material as may indure the fire, having a ſmall hole, at which they are filled with water, and out of which (when the Veſſels are heated) the air doth iſſue forth with a ſtrong and laſting violence. Theſe are frequently uſed for the exciting and contracting of heat in the melting of glaſſes or metals. They may alſo be contrived to be ſerviceable for ſundry other pleaſant uſes, as for the moving of ſails in a chimney corner, the motion of which ſails may be applied to the turning of a ſpit, or the like.

But there is a better invention to

this purpose mentioned in *Cardan*, whereby a spit may be turned (without the help of weights) by the motion of the air that ascends the Chimney; and it may be useful for the roasting of many or great joynts: for as the fire must be increased according to the quantity of meat, so the force of the instrument will be augmented proportionably to the fire. In which contrivance there are these conveniences above the Jacks of ordinary use.

De Varietate Rerum, l. 12. c. 58.

1. It makes little or no noise in the motion.

2. It needs no winding up, but will constantly move of it self, while there is any fire to rarifie the air.

3. It is much cheaper than the other instruments that are commonly used to this purpose. There being required unto it only a pair of sails, which must be placed in that part of the Chimney where it begins to be straightned, and one wheel, to the axis of which the spit line must be fastned, according to this following Diagram.

The

The motion of these sails may likewise be serviceable for sundry other purposes, besides the turning of a spit; for the chiming of bells or other musical devices; and there cannot be any more pleasant contrivance for

continual and cheap motion. It may be useful also for the reeling of yarn, the rocking of a cradle, with divers the like domestick occasions. For (as was said before) any constant motion being given, it is easie for an ingenious artificer to apply it unto various services.

These sails will always move both day and night, if there is but any fire under them, and sometimes though there be none. For if the air without be much colder than that within the room, then must this which is more warm and rarified, naturally ascend through the chimney, to give place unto the more condensed and heavy, which does usually blow in at every chink or cranny, as experience shews.

Unto this kind of motion may be reduced all those representations of living creatures, whether birds, or beasts, invented by *Ctesibius*, which were for the most part performed by the motion of air, being forced up either by *rarefaction*, with fire, or else by *compression*, through the fall

of

of ſome heavier body, as water, which by poſſeſſing the place of the air, did thereby drive it to ſeek for ſome other vent.

I cannot here omit (though it be not altogether ſo pertinent) to mention that late ingenious invention of the winde-gun, which is charged by the forcible compreſſion of air, being injected through a Syringe; the ſtrife and diſtention of the impriſoned air ſerving by the help of little falls or ſhuts within, to ſtop and keep cloſe the vents by which it was admitted. The force of it in the diſcharge is almoſt equal to our powder-guns. I have found upon frequent trials (ſaith *Merſennus*) that a leaden bullet ſhot from one of theſe Guns againſt a ſtone wall, the ſpace of 24 paces from it, will be beaten into a thin plate. It would be a conſiderable addition to this experiment which the ſame Author mentions a little after, whereby he will make the ſame charge of air to ſerve for the diſcharge of ſeveral arrows or bullets after one another,

Phenomena pneumatica, prop. 32.

nother, by giving the air only ſo much room, as may immediatly ſerve to impreſs a violence in ſending away the arrow or bullet, and then ſcrewing it down again to its former confinement, to fit it for another ſhooting. But againſt this there may be many conſiderable doubts, which I cannot ſtand to diſcuſs.

CAP. II.

Of a ſailing Chariot, that may without horſes be driven on the land by the wind, as ſhips are on the ſea.

THE force of wind in the motion of ſails may be applied alſo to the driving of a Chariot, by which a man may ſail on the land as well as by a ſhip on the water. The labour of horſes or other beaſts, which are uſually applied to this purpoſe, being artificially ſupplied by the ſtrength of winds.

That ſuch Chariots are commonly uſed in the Champion plains of *China*, is frequently affirmed by divers credible Authors. *Boterus* mentions that they have been tried alſo in *Spain*, though

De incremento Urbium, l. 1. c. 10.

though with what ſucceſs he doth not ſpecifie. But above all other experiments to this purpoſe, that ſailing Chariot at *Sceveling* in *Holland*, is more eminently remarkable. It was made by the direction of *Stephinus*, & is celebrated by many Authors. **Walchius* affirms it to be of ſo great a ſwiftneſs for its motion, and yet of ſo great a capacity for its burden. *Ut in medio freto ſecundis ventis commiſſas naves, velocitate multis paraſangis poſt ſe relinquat, & paucarum horarum ſpatio, viginti aut triginta milliaria Germanica continuo curſu emetiatur, concreditoſq; ſibi plus minus vectores ſex aut decem, in petitum locum transferat, facillimo illius ad clavum qui ſedet nutu, quaquæ verſum, minimo labore velis commiſſum, mirabile hoc continenti currus navigium dirigentis.* That it did far exceed the ſpeed of any ſhip, though we ſhould ſuppoſe it to be carried in the open ſea with never ſo proſperous wind: and that in ſome few hours ſpace it would convey 6 or 10 perſons 20 or 30 German miles, and all this with very little labour of him that ſitteth at the Stern, who

* *Fabularum de cas. Fab. 9.*

who may easily guide the course of it as he pleaseth.

That eminent inquisitive man *Peireskius*, having travelled to *Sceveling* for the sight and experience of this Chariot, would frequently after with much wonder mention the extreme swiftness of its motion. *Commemorare solebat stuporem quo correptus fuerat cum vento translatus citatissimo non persentiscere tamen, nempe tam citus erat quam ventus.* Though the wind were in it self more swift and strong, yet to passengers in this Chariot it would not be at all discernable, because they did go with an equal swiftness to the wind it self. Men that ran before it, seeming to go backwards; things which seem at a great distance being presently overtaken and left behind. In two hours space it would pass from *Sceveling* to *Putten*, which are distant from one another above 14 *Horaria milliaria* (saith the same Author) that is more than two and forty miles.

Pet. Gassendus. Vita Peireskii, l. 2.

Grotius is very copious and elegant in the celebrating of this invention, and

the

the Author of it, in divers Epigrams.

Ventivolam Tiphys deduxit in æquora navim,
Jupiter in ſtellas, æthereamque domum
Interreſtre ſolum virtus Stevinia, nam nec
Tiphy tuum furat, nec Jovis iſtud opus.

Grotii Poemata, Ep. 19.

And in another place,

Impoſuit plauſtro vectantem carbaſa, malum
An potius navi, ſubdidit ille rotas?
—Scandit æquas navis currus ruit acre prono,
Et merito ditas hic volat, illa natat.

Ep. 5.

These relations did at the first seem unto me, (and perhaps they will so to others) somewhat strange and incredible. But upon farther enquiry I have heard them frequently attested from the particular eye-sight and experience of such eminent persons, whose names I dare not cite in a business of this nature, which in those parts is so very common, and little observed.

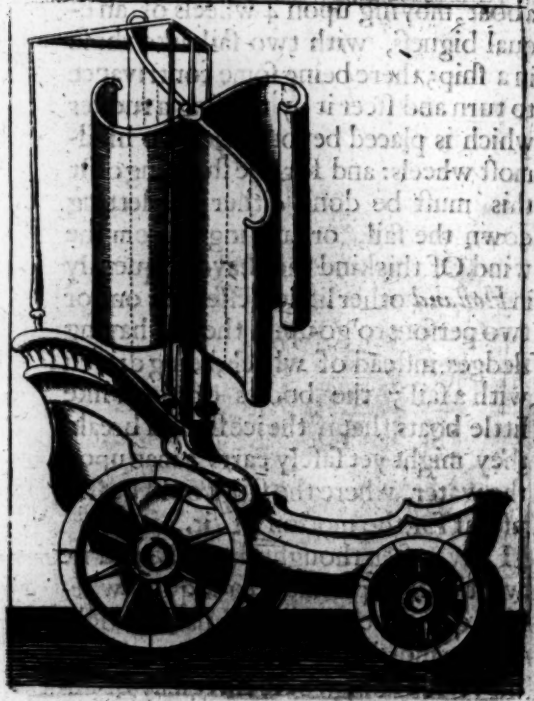
I have not met with any Author who doth treat particularly concerning the manner of framing this Chariot, though *Grotius* mentions an elegant description of it in copper by one *Geynius*: and *Hondius* in one of his large Maps of *Asia*, does give another conjectural description of the like Chariots used in *China*.

Epig. 20. & 21.

The form of it is related to be very simple and plain, after this manner:

The body of it being ſomewhat like a boat, moving upon 4 wheels of an equal bigneſs, with two ſails like thoſe in a ſhip; there being ſome contrivance to turn and ſteer it by moving a rudder which is placed beyond the two hindmoſt wheels: and for the ſtopping of it this muſt be done either by letting down the ſail, or turning it from the wind. Of this kind they have frequently in *Holland* other little Veſſels for one or two perſons to go upon the ice, having ſledges inſtead of wheels, being driven with a ſail; the bodies of them like little boats, that if the ice ſhould break, they might yet ſafely carry a man upon the water, where the ſail would be ſtill uſeful for the motion of it.

I have often thought that it would be worth the experiment to enquire, whether or no ſuch a ſailing-Chariot might not be more conveniently framed with moveable ſails, whoſe force may be impreſt from their motion, equivalent to thoſe in a wind-mill. Their foremoſt wheels (as in other Chariots) for the greater facility, being ſomewhat lower than the other, anſwerable to this figure.



In which the ſails are ſo contrived, that the wind from any Coaſt will have a force upon them to turn them about, and the motion of theſe ſails muſt needs turn the wheels, and conſequently carry on the Chariot it ſelf to any place (though fully againſt the wind) whither it ſhall be directed.

The chief doubt will be, whether in ſuch a contrivance every little ruggedneſs or unevenneſs of the ground, will not cauſe ſuch a jolting of the Chariot as to hinder the motion of its ſails. But this perhaps (if it ſhould prove ſo) is capable of ſeveral remedies.

I have often wondred, why none of our Gentry who live near great Plains, and ſmooth Champions, have attempted any thing to this purpoſe. The experiments of this kind being very pleaſant, and not coſtly: what could be more delightful or better husbandry, than to make uſe of the *wind* (which coſts nothing, and eats nothing) inſtead of *horſes?* This being very eaſie to be effected by thoſe,

the convenience of whose habitations doth accommodate them for such experiments.

CAP. III.

Concerning the fixed Automata, *Clocks, Spheres, representing the heavenly motions: The several excellencies that are most commendable in such kind of contrivances.*

THE second kind of ἀυτόματα were described to be such Engines, as did receive a regular and lasting motion from something belonging to their own frame, whether weights, or springs, &c.

They are usually distinguished into ἀυτόματα.

{ στάτα, fixed and stationary.
{ φερόμενα, moveable and transient.

1. The fixed are such as move only according to their several parts, and not according to their whole frame; In which, though each wheel hath a distinct rotation, yet the whole doth still remain unmoved. The chiefest kind

kind of these are the Clocks and Watches in ordinary use, the framing of which is so commonly known by every Mechanick, that I shall not trouble the Reader with any explication of it. He that desires fuller satisfaction, may see them particularly described by * *Cardan*, † D. *Flood*, and others.

The first invention of these (saith *Pancirollus*) was taken from that experiment in the multiplication of wheels mentioned in *Vitruvius*, where he speaks of an instrument whereby a man may know how many miles or paces he doth go in any space of time, whether or no he do pass by water in a boat or ship, or by land in a Chariot or Coach: they have been contrived also into little pocket-instruments, by which after a man hath walked a whole day together, he may easily know how many steps he hath taken. I forbear to enter upon a larger explication of these kind of Engines, because they are impertinent unto the chief business that

* *De Varietate Rer. l. 9. c. 47.*

† *Tract. 2. part. 7. l. 2. cap. 4. Reper. Tit. 10.*

Architect. l. 10. c. 14.

I have propoſed for this diſcourſe. The Reader may ſee them more particularly deſcribed in the above cited place of *Vitruvius*, in * *Cardan.* † *Beſſonius*, and others; I have here only mentioned them, as being the firſt occaſion of the chiefeſt αὐτόματα that are now in uſe.

* *Subtil.*
† *Theatrum inſtrumentorum.*
Wecker de ſecret. l. 17. c. 32.

Of the ſame kind with our Clocks and Watches (though perhaps more elaborate and ſubtil) was that ſphere invented by *Archimedes*, which did repreſent the heavenly motions: the diurnal and annual courſes of the ſun, the changes and aſpects of the Moon, &c. This is frequently celebrated in the writings of the Ancients, particularly in that known *Epigram* of *Claudian*:

Mentioned by *Cicero. Tuſcul. Quæſt. l. 1. item De Nat. Deorum l. 2.*

Jupiter in parvo cum cerneret æthera vitro,
Riſit, & ad Superos talia dicta dedit;
Huccine mortalis progreſſa potentia curæ?
Jam mens in fragili luditur orbe labor.
Jura poli, rerumque fidem, legeſque Deorum,
Ecce Syracuſius tranſtulit arte ſenex.
*Incluſius variis famulatur * ſpiritus aſtris,*
Et vivum certis motibus urget opus.

* The ſecret force from which the motion was impreſſed.

Per-

Percurrit proprium mentitus Signifer annum;
Et simulata novo Cynthia mense redit.
Famq; suum volvens audax industria mundum
Gaudet, & humanâ sidera mente regit.
Quid falso insontem tonitru Salmonea miror?
Æmula naturæ parva reperta manus.

Excellently Translated by
T. Randolph.

Jove saw the heavens fram'd in a little *glass*,
And laughing, to the gods these words did pass;
Comes then the power of mortal cares so far?
In brittle orbs my labours acted are.
The statutes of the Poles, the faith of things,
The laws of Gods, this *Syracusian* brings
Hither by art: Spirits inclos'd attend
Their several spheres, and with set motions bend
The living work; each year the feigned Sun,
Each month returns the counterfeited Moon.
And viewing now her world, bold industry
Grows proud, to know the heavens his subjects be.
Believe, *Salmoneus* hath false thunders thrown,
For a poor hand is natures rival grown.

But that this Engine should be made of glass, is scarce credible. *Lactantius* mentioning the relation of it, affirms it to consist of brass, which is more likely. It may be the outside or case was glass, and the frame it self of brass. *Cœlius Rhodoginus*, speaking of the wondrous art in the contrivance

Instit. l. 2. c. 5.

Lect. l. est t. 2. c. 16.

of this Sphere, breaks out into this quære, *Nonne igitur miraculorum omnium maximum miraculum est homo?* He might have said *Mathematicus:* And another to this purpose, *Sic manus ejus naturam, ut natura ipsa manum imitata putetur. Pappus* tells us, that *Archimedes* writ a Book *de Sphæropœia* concerning the manner of framing such Engines, and after him *Posidonius* composed another discourse on the same subject, though now either the ignorance or the envy of time hath deprived us of both those works. And yet the art it self is not quite perished, for we read of divers the like contrivances in these latter times. *Agrippa* affirms that he himself had seen such a sphere, and *Ramus* tells us how he beheld two of them in *Paris*, the one brought thither amongst other spoils from *Sicily*, and the other out of *Germany*. And it is commonly reported, that there is yet such a sphere at *Strasburgh* in *Germany*. * *Rivalius* relates how *Marinus Burgesius* a *Norman* made two of them in *France* for the King. And

Guid. Ubaldus præf ad Mechan

Collect. Mathem. Præm. ad l. 8.

De Vanit. Scient. cap. 22. Schol. Math. l. 1. So *Cardan too, l. 17. Monamb. in Mecha. Arist. com. c. 1. Dr.* Hackwel, *Apol. l. 2. c. 10. sect. 1.*

* *De vita Archimedis.*

And perhaps theſe latter (ſaith he) were more exact than the former, becauſe the heavenly revolutions are now much better underſtood then before. And beſides, it is queſtionable, whether the uſe of ſteel-ſprings was known in thoſe ancient times; the application of which unto theſe kind of ſpheres muſt needs be much more convenient then weights.

'Tis related alſo of the Conſul *Boethius*, that amongſt other Mathematical contrivances, (for which he was famous) he made a ſphere to repreſent the Suns motion, which was ſo much admired, and talked of in thoſe times, that *Gundibaldus* King of *Burgundie*, did purpoſely ſend over Embaſſadors to *Theodoricus* the Emperour, with intreaties that he would be a means to procure one of theſe ſpheres from *Boethius*; the Emperor thinking hereby to make his kingdom more famous and terrible unto foreign Nations, doth write an Epiſtle to *Boethius*, perſwading him to ſend this inſtrument. *Quoties non ſunt crediturî*

Caſſiodor. Chron. Pet. Bertius præf. ad Conſolat. Philoſ.

quod viderint? Quoties hanc veritatem luſoria ſomnia putabunt? Et quando fuerint à ſtupore converſi, non audebunt ſe æquales nobis dicere, apud quos ſciunt ſapientes talia cogitaſſe. So much were all theſe kind of inventions admired in thoſe ruder and darker times; whereas the inſtruments that are now in uſe amongſt us (though not ſo much extolled) yet do altogether equal (if not exceed) the other both in uſefulneſs and ſubtilty. The chiefeſt of theſe former Engines receiving their motion from weights, and not from ſprings, which (as I ſaid before) are of later and more excellent invention.

Polyd. Virgil. de invent. rerum l. 2. c. 5. Cardan Subt. l. 17.

The particular circumſtances for which the *Automata* of this kind, are moſt eminent, may be reduced to theſe four.

1. The laſtingneſs of their motion, without needing any new ſupply; for which purpoſe there have been ſome Watches contrived to continue without winding up for a week together, or longer.

2. The

2. The easiness and simplicity of their composition; Art it self being but the facilitating and contracting of ordinary operations, therefore the more easie and compendious such inventions are, the more artificial should they be esteemed. And the addition of any such unnecessary parts, as may be supplied some other way, is a sure sign of unskilfulness and ignorance. Those antiquated Engines that did consist of such a needless multitude of wheels, and springs, and screws, (like the old *hypotheses* of the heavens) may be compared to the notions of a confused knowledg, which are always full of perplexity and complications, and seldom in order; whereas the inventions of art are more regular, simple and perspicuous, like the apprehensions of a distinct and thoroughly informed judgment. In this respect the manner of framing the ordinary *Automata*, hath been much bettered in these latter times above the former, and shall hereafter perhaps be yet more advantaged.

These

Theſe kind of experiments (like all other humane arts) receiving additions from every days experiment.

To this purpoſe there is an invention conſiſting only of one hollow orb or wheel, whereby the hours may be as truly diſtinguiſhed, as by any ordinary clock or watch. This wheel ſhould be divided into ſeveral cavities, through each of which ſucceſſively either ſand or water muſt be contrived to paſs; the heavineſs of theſe bodies (being always in the aſcending ſide of the wheel) muſt be counterpoiſed by a plummet that may be faſtned about the pulley on the axis: this plummet will leiſurely deſcend, according as the ſand by running out of one cavity into the next, doth make the ſeveral parts of the wheel lighter or heavier, and ſo conſequently there will be produced an equal and laſting motion, which may be eaſily applied to the diſtinction of hours.

3. The multitude and variety of thoſe ſervices for which they may be

be useful. Unto this kind may we refer those Watches, by which a man may tell not only the hour of the day, but the minute of the hour, the day of the month, the age and aspects of the Moon, &c. Of this nature likewise was that larum mentioned by *Walchius*, which though it were but two or three inches big, yet would both wake a man, and of it self light a candle for him at any set hour of the night. And those weights or springs which are of so great force as to turn a mill, (as some have been contrived) may be easily applied to more various and difficult labours.

Fab. 9.

Ramel. fig. 130.

4. The littleness of their frame. *Nunquam ars magis quam in minimis nota est* (saith *Aquinas*). The smalness of the Engine doth much commend the skill of the Artificer; to this purpose there have been Watches contrived in the form and quantity of a Jewel for the ear, where the striking of the minutes may constantly whisper unto us, how our lives do slide away

Jacks no bigger than a walnut, to turn any joint of meat.

away by a ſwift ſucceſſion. *Cardan* tells us of a Smith who made a Watch in the Jewel of a ring, to be worn on the finger, which did ſhew the hours, (*non ſolum ſagitta, ſed ictu*) not only by the hand, but by the finger too (as I may ſay) by pricking it every hour.

De ſubtil. l. 2. item l. 17.

CAP. IV.

Of the movable and Gradient Automata, repreſenting the motions of living creatures, various ſounds, of birds, or beaſts, and ſome of them articulate.

THus much of thoſe Automata, which were ſaid to be fixed and ſtationary.

The other kind to be enquired after, are thoſe that are movable and tranſient, which are deſcribed to be ſuch engines as move not only according to their ſeveral parts, but alſo according to their whole frames. Theſe are again diſtinguiſhable into two ſorts:

1. *Gra-*

1. *Gradient.*
2. *Volant.*

1. The *Gradient* or *ambulatory*, are such as require some *basis* or bottom to uphold them in their motions. Such were those strange inventions (commonly attributed to *Dædalus*) or self-moving statues, which (unless they were violently detained) would of themselves run away, * *Aristotle* affirms that *Dædalus* did this by putting quick-silver into them. But this would have been too gross a way for so excellent an Artificer; it is more likely that he did it with wheels and weights. Of this kind likewise were *Vulcans Tripodes*, celebrated by *Homer*, that were made to move up and down the house, and fight with one another. He might as well have contrived them into Journey-men statues, each of which with a hammer in his hand should have worked at the forge.

Plato in Menone. Arist. Polit. l. 1. c. 3.

* *De Anima. l. 1. c. 3.*

Iliad. 18.

There have been also chariots driven by the force of a spring contrived within them.

But amongst these fighting images, that in *Cardan* may deserve a mention, which holding in its hand a golden apple, beautified with many costly Jewels;

De Variet. rerum, l. 12. c. 58.

Jewels; if any man offered to take it, the ſtatue preſently ſhot him to death. The touching of this apple ſerving to diſcharge ſeveral ſhort bows, or other the like inſtruments that were ſecretly couched within the body of the image. By ſuch a treachery was King *Chennetus* murdered (as *Boethius* relates).

It is ſo common an experiment in theſe times to repreſent the perſons and actions of any ſtory by ſuch ſelf-moving images, that I ſhall not need to explain the manner how the wheels and ſprings are contrived within them.

Fab. 9. There have been other inventions to move on the water. *Navigium ſponte mobile, ac ſui remigii autorim, faciam nullo negotio,* ſaith *Scaliger, Exerc.* 326.

Amongſt theſe gradient *Automata*, that iron Spider mentioned in *Walchius*, is more eſpecially remarkable, which being but of an ordinary bigneſs, beſides the outward ſimilitude, (which was very exact) had the ſame kind of motions with a living ſpider, and did creep up and down as if it had been alive. It muſt needs argue a wonderfull art, and acurateneſs, to contrive all the inſtruments requiſite for ſuch a

a motion in ſo ſmall a frame.

There hath been alſo other motions contrived from Magnetical qualities, which will ſhew the more wonderful, becauſe there is no apparent reaſon of their motion, there being not the leaſt contiguity or dependance upon any other body that may occaſion it; but it is all one as if they ſhould move up and down in the open air. Get a glaſs ſphere, fill it with ſuch liquors as may be clear of the ſame colour, immixable, ſuch as are oyl of Tartar, and ſpirit of wine: In which, it is eaſie ſo to poiſe a little globe or other ſtatue, that it ſhall ſwim in the center. Under this glaſs ſphere, there ſhould be a loadſtone concealed, by the motion of which, the ſtatue (having a needle touched within it) will move up and down, and may be contrived to ſhew the hour or ſign. See ſeveral inventions of this kind in *Kircher de arte Magnetica, l.* 2.

There have been ſome artificial images, which beſides their ſeveral poſtures in walking up and down, have

have been made also to give several sounds, whether of birds, as Larks, Cuckooes, &c. or beasts, as Hares, Foxes. The voices of which creatures shall be rendered as clearly and distinctly, by these artificial images, as they are by those natural living bodies, which they represent.

There have been some inventions also which have been able for the utterance of articulate sounds, as the speaking of certain words. Such are some of the *Egyptian* idols related to be. Such was the brazen head made by Fryer *Bacon*, and that statue in the framing of which *Albertus Magnus* bestowed thirty years, broken by *Aquinas*, who came to see it, purposely that he might boast, how in one minute he had ruined the labour of so many years.

Cæl. Rhod. lect. Ant. l. 2. c. 17. Maiolus Colloq.

Now the ground and reason how these sounds were contrived, may be worth our inquiry.

First then, for those of birds or beasts, they were made from such pipes or calls, as may express the several

veral tones of those creatures which are represented: these calls are so commonly known and used, that they need not any further explication.

But now about articulate sounds there is much greater difficulty. *Wal-chius* thinks it possible entirely to preserve the voice, or any words spoken, in a hollow trunk, or pipe, and that this pipe being rightly opened, the words will come out of it in the same order wherein they were spoken. Somewhat like that cold Country, where the peoples discourse doth freeze in the air all winter, and may be heard in the next Summer, or at a great thaw. But this conjecture will need no refutation. *Fab. 9.*

The more substantial way for such a discovery, is by marking how nature her self doth imploy the several instruments of speech, the tongue, lips, throat, teeth, &c. To this purpose the Hebrews have assigned each letter unto its proper instrument. And besides, we should observe what inarticulate sounds do resemble any of

Bacon *Nat. Hist. Exper.* 199 200.

the particular letters. Thus we may note the trembling of water to be like the letter *L*, the quenching of hot things to the letter *Z*, the sound of strings, unto the letter *Ng*, the jirking of a switch the letter *Q*, &c. By an exact observation of these particulars, it is (perhaps) possible to make a statue speak some words.

CAP. V.

Concerning the possibility of framing an Ark for submarine Navigations. The difficulties and conveniences of such a contrivance.

Tract. de Magnetis proprietatibus.

IT will not be altogether impertinent unto the discourse of these gradient *Automata*, to mention what *Mersennus* doth so largely and pleasantly descant upon, concerning the making of a ship, wherein men may safely swim under water.

That such a contrivance is feasible and may be effected, is beyond all question, because it hath been already

dy experimented here in *England* by *Cornelius Dreble*; but how to improve it unto publick use and advantage, so as to be serviceable for remote voyages, the carrying of any considerable number of men, with provisions and commodities, would be of such excellent use as may deserve some further inquiry.

Concerning which there are two things chiefly considerable:

The { many difficulties with their remedies, / great conveniences.

1. The difficulties are generally reducible to these three heads.

1. The letting out, or receiving in any thing, as there shall be occasion, without the admission of water. If it have not such a convenience, these kind of voyages must needs be very dangerous and uncomfortable, both by reason of many noisome offensive things, which should be thrust out, and many other needful things which should be received in. Now herein will consist the difficulty, how to con-

trive the opening of this veſſel ſo, that any thing may be put in or out, and yet the water not ruſh into it with much violence, as it doth uſually in the leak of a ſhip.

In which caſe this may be a proper remedy; let there be certain leather bags made of ſeveral bigneſſes, which for the *matter* of them ſhould be both *tractable* for the uſe and managing of them, and *ſtrong* to keep out the water; for the *figure* of them, being long and open at both ends. Anſwerable to theſe, let there be divers windows, or open places in the frame of the ſhip, round the ſides of which one end of theſe bags may be fixed, the other end coming within the ſhip being to open and ſhut as a purſe. Now if we ſuppoſe this bag thus faſtned, to be tyed cloſe about towards the window, then any thing that is to be ſent out, may be ſafely put into that end within the ſhip, which being again cloſe ſhut, and the other end looſened, the thing may be ſafely ſent out without the admiſſion of any water.

So

So again, when any thing is to be taken in, it muſt be firſt received into that part of the bag towards the window, which being (after the thing is within it) cloſe tyed about, the other end may then be ſafely opened. It is eaſie to conceive, how by this means any thing or perſon may be ſent out, or received in, as there ſhall be occaſion; how the water, which will perhaps by degrees leak into ſeveral parts, may be emptied out again, with divers the like advantages. Though if there ſhould be any leak at the bottom of the Veſſel, yet very little water would get in, becauſe no air could get out.

2. The ſecond difficulty in ſuch an Ark will be the *motion* or *fixing* of it according to occaſion; The *directing* of it to ſeveral places, as the voyage ſhall be deſigned, without which it would be very uſeleſs, if it were to remain only in one place, or were to remove only blindfold, without any certain direction; And the contrivance of this may ſeem very diffi-

cult, becauſe theſe ſubmarine Navigators will want the uſual advantages of winds and tides for motion, and the ſight of the heavens for direction.

But theſe difficulties may be thus remedied; As for the *progreſſive* motion of it, this may be effected by the help of ſeveral Oars, which in the outward ends of them, ſhall be like the fins of a fiſh to contract and dilate. The paſſage where they are admitted into the ſhip being tyed about with ſuch leather bags (as were mentioned before) to keep out the water. It will not be convenient perhaps that the motion in theſe voyages ſhould be very ſwift, becauſe of thoſe obſervations and diſcoveries to be made at the bottom of the ſea, which in a little ſpace may abundantly recompence the ſlowneſs of its progreſs.

If this Ark be ſo ballaſt as to be of equal weight with the like magnitude of water, it will then be eaſily movable in any part of it.

As for the *aſcent* of it, this may be eaſily contrived, if there be ſome great weight

weight at the bottom of the ſhip (being part of its ballaſt) which by ſome cord within may be looſned from it; As this weight is let lower, ſo will the ſhip aſcend from it (if need be) to the very ſurface of the water; and again, as it is pulled cloſe to the ſhip, ſo will it *deſcend.*

For *direction* of this Ark, the Mariners needle may be uſeful in reſpect of the *latitude* of places; and the courſe of this ſhip being more regular than others, by reaſon it is not ſubject to Tempeſts or unequal winds, may more certainly guide them in judging of the *longitude* of places.

3. But the greateſt difficulty of all will be this, how the air may be ſupplied for reſpiration: How conſtant fires may be kept in it for light, and the dreſſing of food; how thoſe viciſſitudes of rarefaction and condenſation may be maintained.

It is obſerved, that a barrel or cap, whoſe cavity will contain eight cubical feet of air, will not ſerve a Urinator or Diver for reſpiration, a-

bove one quarter of an hour; the breath which is often ſucked in and out, being ſo corrupted by the mixture of vapours, that nature rejects it as unſerviceable. Now in an hour a man will need at leaſt 360 reſpirations, betwixt every one of which there ſhall be 10 ſecond minutes, and conſequently a great change and ſupply of air will be neceſſary for many perſons, and any long ſpace.

And ſo likewiſe for the keeping of fire; a cloſe Veſſel containing ten cubical feet of air, will not ſuffer a wax candle of an ounce to burn in it above an hour before it be ſuffocated, though this proportion (ſaith *Merſennus*) doth not equally increaſe for ſeveral lights, becauſe four flames of an equal magnitude will be kept alive the ſpace of 16 ſecond minutes, though one of theſe flames alone in the ſame Veſſel will not laſt above 25, or at moſt 30 ſeconds, which may be eaſily tried in large glaſs bottles, having wax candles lighted in them, and with their mouths inverted in water.

For

For the reſolution of this difficulty, though I will not ſay that a man may by cuſtome (which in other things doth produce ſuch ſtrange incredible effects) be inabled to live in the open water as the fiſhes do, the inſpiration and expiration of water ſerving inſtead of air, this being uſual with many fiſhes that have lungs; yet it is certain that long uſe and cuſtome may ſtrengthen men againſt many ſuch incoveniences of this kind, which to unexperienced perſons may prove very hazardous: and ſo it will not perhaps be unto theſe ſo neceſſary, to have the air for breathing ſo pure and defecated as is required for others.

But further, there are in this caſe theſe three things conſiderable.

1. That the Veſſel it ſelf ſhould be of a large capacity, that as the air in it is corrupted in one part, ſo it may be purified and renewed in the other: or if the meer refrigeration of the air would fit it for breathing, this might be ſomewhat helped with bellows.

bellows, which would cool it by motion.

2. It is not altogether improbable, that the lamps or fires in the middle of it, like the reflected beams in the first Region, rarefying the air, and the circumambient coldness towards the sides of the Vessel, like the second Region, cooling and condensing of it, would make such a vicissitude and change of air, as might fit it for all its proper uses.

Harmon. l. 4. prop. 6. Monit.

3. Or if neither of these conjectures will help, yet *Mersennus* tells us in another place, that there is in *France* one *Barricus* a Diver, who hath lately found out another art, whereby a man might easily continue under water for six hours together; and whereas ten cubical feet of air will not serve another Diver to breathe in, for half an hour, he by the help of a cavity, not above one or two foot at most, will have breath enough for six hours, and a lanthorn scarce above the usual size to keep a candle burning as long as a man please, which

(if

(if it be true, and were commonly known) might be a ſufficient help againſt this greateſt difficulty.

As for the many advantages and conveniences of ſuch a contrivance, it is not eaſie to recite them.

1. 'Tis *private*; a man may thus go to any coaſt of the world inviſibly, without being diſcovered or prevented in his journey.

2. 'Tis *ſafe*; from the uncertainty of *Tides*, and the violence of *Tempeſts*, which do never move the ſea above five or ſix paces deep. From *Pirates* and *Robbers* which do ſo infeſt other voyages; From ice and great froſts, which do ſo much endanger the paſſages towards the Poles.

3. It may be of very great advantage againſt a Navy of enemies, who by this means may be undermined in the water and blown up.

4. It may be of ſpecial uſe for the relief of any place that is beſieged by water, to convey unto them inviſible ſupplies: and ſo likewiſe for the ſurpriſal of any place that is acceſſible by water.

5. It

5. It may be of unſpeakable benefit for ſubmarine experiments and diſcoveries: as,

The ſeveral proportions of ſwiftneſs betwixt the aſcent of a bladder, cork, or any other light ſubſtance, in compariſon to the deſcent of ſtones or lead. The deep caverns and ſubterraneous paſſages where the ſea-water in the courſe of its circulation, doth vent it ſelf into other places, and the like. The nature and kinds of fiſhes, the ſeveral arts of catching them, by alluring them with lights, by placing divers nets about the ſides of this Veſſel, ſhooting the greater ſort of them with guns, which may be put out of the ſhip by the help of ſuch bags as were mentioned before, with divers the like artifices and treacheries, which may be more ſucceſſively practiſed by ſuch who live ſo familiarly together. Theſe fiſh may ſerve not only for food, but for fewel likewiſe, in reſpect of that oyl which may be extracted from them; the way of dreſſing meat by lamps, being

ing

ing in many reſpects the moſt convenient for ſuch a voyage.

The many freſh ſprings that may probably be met with in the bottom of the ſea, will ſerve for the ſupply of drink and other occaſions.

But above all, the diſcovery of ſubmarine treaſures is more eſpecially conſiderable, not only in regard of what hath been drowned by wrecks, but the ſeveral precious things that grow there, as Pearl, Coral Mines, with innumerable other things of great value, which may be much more eaſily found out, and fetcht up by the help of this, than by any other uſual way of the Urinators.

To which purpoſe, this great Veſſel may have ſome leſſer Cabins tyed about it, at various diſtances, wherein ſeveral perſons, as Scouts, may be lodged for the taking of obſervations, according as the Admiral ſhall direct them. Some of them being frequently ſent up to the ſurface of the water, as there ſhall be occaſion.

All

All kind of arts and manufactures may be exercised in this Vessel. The observations made by it, may be both written, and (if need were) printed here likewise. Several Colonies may thus inhabit, having their Children born and bred up without the knowledg of land, who could not chuse but be amazed with strange conceits upon the discovery of this upper world.

I am not able to judge what other advantages there may be suggested, or whether experiment would fully answer to these notional conjectures. But however, because the invention did unto me seem ingenious and new, being not impertinent to the present enquiry, therefore I thought it might be worth the mentioning.

CAP.

CAP. VI.

Of the volant Automata, Archytas his Dove, and Regiomontanus his Eagle. The possibility and great usefulness of such inventions.

THE *volant* or flying *Automata* are such Mechanical contrivances, as have a self-motion, whereby they are carried aloft in the open air, like the flight of Birds. Such was that wooden Dove made by *Archytas*, a Citizen of *Tarentum*, and one of *Plato's* acquaintance. And that wooden Eagle framed by *Regiomontanus* at *Noremberg*, which by way of triumph, did fly out of the City to meet *Charles* the fift. This later Author is also reported to have made an iron fly, *Quæ ex artificis manu egressa, convivas circumvolitavit, tandemque veluti defessa in Domini manus reversa est*, which when he invited any of his friends, would fly to each of them round the table, and at length (as being weary) return unto its Master.

Diog. Laer. l. 8.

Pet. Crinitus de honest. discip. l. 17. c. 12.

Ramus Schol. Mathem. l. 2.

Dubartas 6 days 1w.

J. Dee Preface to Euclid.

Cardan

De Variet. rerum lib. 12. c. 58.

Cardan ſeems to doubt the poſſibility of any ſuch contrivance; his reaſon is, becauſe the inſtruments of it muſt be firm, and ſtrong, and conſequently they will be too heavy to be carried by their own force; but yet (ſaith he) if it be a little helped in the firſt riſing; and if there be any wind to aſſiſt it in the flight, then there is nothing to hinder, but that ſuch motions may be poſſible. So that he doth in effect grant as much as may be ſufficient for the truth and credit of thoſe ancient relations; and to diſtruſt them without a ſtronger argument, muſt needs argue a blind and perverſe incredulity. As for his objection concerning the heavineſs of the materials in ſuch an invention, it may be anſwered, that it is eaſie to contrive ſuch ſprings and other inſtruments, whoſe ſtrength ſhall much exceed their heavineſs. Nor can he ſhew any cauſe why theſe Mechanical motions may not be as ſtrong, (though not ſo laſting) as the natural ſtrength of living creatures.

Scaliger

Scaliger conceives the framing of such volant *Automata*, to be very easie. *Volantis columbæ machinulam, cujus autorem Archytam tradunt, vel facillime profiteri audeo.* Those ancient motions were thought to be contrived by the force of some included air: So *Gellius*: *Ita erat scilicet libramentis suspensum, & autâ spiritus inclusâ atque occultâ constitum, &c.* As if there had been some lamp, or other fire within it, which might produce such a forcible rarefaction, as should give a motion to the whole frame.

Subtil. Exercit. 326.

Noct. Attic. l. 10. cap. 12. where he thinks it so strange an invention that he styles *Res abhorrens à fide Athan. Kircher de Magnete l. 2. par. 4.* Poem: doth promise a large discourse concerning these kind of inventions in another Treatise which he styles *Oedipus Aegyptiacus.*

But this may be better performed by the strength of some such spring as is commonly used in watches; this spring may be applied unto one wheel, which shall give an equal motion to both the wings; these wings having unto each of them another smaller spring by which they may be contracted and lifted up: So that being forcibly depressed by the strength of the great and stronger spring, and lifted up again by the other two. According to this suppo-

sition, it is easie to conceive how the motion of flight may be performed and continued.

The wings may be made either of *several substances joyned*, like the feathers in ordinary fowl, as *Dædalus* is feigned to contrive them, according to that in the Poet.

Ovid. Metam. l. 8.

--Ignotas animum dimittit in artes,
Naturamque novat, nam ponit in ordine pennas
A minimo cœptas longam breviore sequente,
Ut clivo crevisse putes, &c.

Or else of *one continuate substance*, like those of Bats. In framing of both which, the best guidance is to follow (as neer as may be) the direction of nature; this being but an imitation of a natural work. Now in both these, the strength of each part is proportioned to the force of its imployment. But nothing in this kind can be perfectly determined without a particular trial.

Though the composing of such motions may be a sufficient reward to any ones industry in the searching af-

after them, as being in themſelves of excellent curioſity; yet there are ſome other inventions depend upon them of more general benefit and greater importance. For if there be any ſuch artificial contrivances that can fly in the air, (as is evident from the former relations, together with the grounds here ſpecified, and I doubt not, may be eaſily effected by a diligent and ingenious artificer) then it will clearly follow, that it is poſſible alſo for a man to fly himſelf: It being eaſie from the ſame grounds to frame an inſtrument, wherein any one may ſit, and give ſuch a motion unto it as ſhall convey him aloft through the air. Then which there is not any imaginable invention that could prove of greater benefit to the world, or glory to the Author. And therefore it may juſtly deſerve their enquiry, who have both leiſure and means for ſuch experiments.

But in theſe practical ſtudies, unleſs a man be able to go to the tryal of things, he will perform but

little. In ſuch matters,

Horace. *--Studium ſine divite venâ,*

(as the Poet ſaith) a general ſpeculation, without particular experiment, may conjecture at many things, but can certainly effect nothing. And therefore I ſhall only propoſe unto the world, the Theory and general grounds that may conduce to the eaſie and more perfect diſcovery of the ſubject in queſtion, for the encouragement of thoſe that have both minds and means for ſuch experiments. This ſame Scholars fate,

Res anguſta domi, and
--curta ſupellex.

is that which hinders the promoting of learning in ſundry particulars, and robs the world of many excellent inventions. We read of *Ariſtotle*, that he was allowed by his pupil *Alexander* 800 talents a year, for the payment of Fiſhers, Fowlers, and Hunters, who were to bring him in ſeveral creatures, that ſo by his particular experience of their parts and diſpoſitions, he might be more fitly prepared

pared to write of their natures. The reason why the world hath not many *Aristotles* is, because it hath so few *Alexanders*.

Amongst other impediments of any strange invention or attempts, it is none of the meanest discouragements, that they are so generally derided by common opinion, being esteemed only as the dreams of a melancholy and distempered fancy. *Eusebius* speaking with what necessity every thing is confined by the laws of nature, and the decrees of providence, so that nothing can go out of that way, unto which naturally it is designed; as a fish cannot reside on the land, nor a man in the water, or aloft in the air, infers, that therefore none will venture upon any such vain attempt, as passing in the air, ἢ μελαγχολίας νοσήματα ἂν πειπέσοι, unless his brain be a little crazed with the humour of melancholy; whereupon he advises that we should not in any particular endeavour to transgress the bounds of nature, οὐδὲ ἄπτερον ἔχοντα τὸ σῶμα, τὰ τῶν

Contra Hierocl. confut. l. 1.

πτηνῶν ἐπιτηδεύειν, and since we are naturally destitute of wings, not to imitate the flight of Birds. That saying of the Poet,

Virgil. Æneid. l. 6.

Demens qui nimbos & non imitabile fulmen, &c.

hath been an old censure applied unto such as ventured upon any strange or incredible attempt.

Hence may we conceive the reason, why there is so little intimation in the writings of antiquity, concerning the possibility of any such invention. The Ancients durst not so much as mention the art of flying, but in a fable.

Dædalus, ut fama est, fugiens Minoia regna,
Præpetibus pennis ausus se credere cælo,
Insuetum per iter gelidas enavit ad arctos, &c.

It was the custom of those former ages, in their overmuch gratitude, to advance the first Authors of any useful discovery, amongst the number of their gods. And *Dædalus* being so famous amongst them for

sundry

ſundry Mechanical inventions (eſpecially the ſails of ſhips) though they did not for theſe place him in the heavens, yet they have promoted him as near as they could, feigning him to fly aloft in the air, when as he did but fly in a ſwift ſhip, as *Diodorus* relates the Hiſtorical truth, on which that fiction is grounded. So *Euſebius* too.

CAP. VII.

Concerning the Art of flying. The ſeveral ways whereby this hath been or may be attempted.

I Have formerly in two other * Diſcourſes mentioned the poſſibility of this art of flying, and intimated a further inquiry unto it, which is a kind of engagement to ſome fuller diſquiſitions and conjectures to that purpoſe. * World in the Moon, cap. 14. Mercury, or the ſecret and ſwift Meſſenger c. 4

There are four ſeveral wayes whereby this flying in the air, hath been or may be attempted. Two of them by the ſtrength of other things, and

two of them by our own strength.

1. By spirits or Angels.

2. By the help of fowls.

3. By wings fastned immediately to the body.

4. By a flying chariot.

Zanch. de oper. pars 1. l. 4.

1. For the first we read of divers that have passed swiftly in the air, by the help of spirits and Angels, whether good Angels, a * *Elias* was carried into heaven in a fiery chariot: as † *Philip* was conveyed to *Azotus*, and *Habbacuck* from Jewry to Babylon, and back again immediately: Or by evil Angels, as our Saviour was carried by the Devil to the top of a high mountain, and to the pinacle of the Temple. Thus witches are commonly related to pass unto their usual meetings in some remote place; and as they do sell windes unto Mariners, so likewise are they sometimes hired to carry men speedily through the open air. *Acosta* affirms that such kind of passages are usual amongst divers Sorcerers with the Indians at this day.

* 2 Kings 2. 11.

† Acts 8. 39.

Dan. Apoc. 39.

Luke 4.

Erastus de Lamiis.

Hist. Ind. l. 5. c. 26.

So

So *Kepler* in his Astronomical dream doth fancy a Witch to be conveyed unto the Moon by her Familiar.

Simon Magus was so eminent for miraculous sorceries, that all the people in *Samaria*, from the least to the greatest, did esteem him *as the great power of God.* And so famous was he at *Rome*, that the Emperour erected a statue to him with this Inscription, *Simoni Deo Sancto.* 'Tis storied of this Magician, that having challenged Saint *Peter* to do miracles with him, he attempted to fly from the Capitol to the Aventine hill. But when he was in the midst of the way, Saint *Peters* prayers did overcome his sorceries, and violently bring him to the ground, in which fall having broke his thigh, within a while after he died.

Acts 8. 10.

Hegesip. l. 3. c. 2. Pol. Virgil. de Inven. Rerum. l. 8 c. 3. Pet. Crinitus de Honestâ Disciplin. l. 8. c. 1. mistrusts this relation as fabulous. *Non enim Lucas hoc omisisset.*

But none of all these relations may conduce to the discovery of this experiment, as it is here enquired after, upon *natural* and *artificial* grounds.

2. There are others who have con-

conjectured a possibility of being conveyed through the air by the help of Fowls; to which purpose that fiction of the *Ganza's*, is the most pleasant and probable. They are supposed to be great fowl of a strong lasting flight, and easily tamable. Divers of which may be so brought up as to joyn together in carrying the weight of a man, so as each of them shall partake his proportionable share of the burden; and the person that is carried may by certain reins direct and steer them in their courses. However this may seem a strange proposal, yet it is not certainly more improbable, than many other arts, wherein the industry of ingenious men hath instructed these brute creatures. And I am very confident, that one whose genius doth enable him for such kind of experiments, upon leisure, and the advantage of such helps as are requisite for various and frequent trials might effect some strange thing by this kind of enquiry.

'Tis reported as a custom amongst the

the *Leucatians*, that they were wont upon a ſuperſtition to precipitate a man from ſome high cliffe into the Sea, tying about him with ſtrings at ſome diſtance, many great fowls, and fixing unto his body divers feathers ſpread, to break the fall; which (ſaith the learned *Bacon*, if it were diligently and exactly contrived) would be able to hold up, and carry any proportionable weight; and therefore he adviſes others to think further upon this experiment, as giving ſome light to the invention of the art of flying. *Nat. Hiſt. experim.* 886.

3. 'Tis the more obvious and common opinion that this may be effected by wings faſtned immediately to the body, this coming neareſt to the imitation of nature, which ſhould be obſerved in ſuch attempts as theſe. This is that way which *Fredericus Hermannus* in his little diſcourſe *de Arte volandi*, doth only mention and inſiſt upon. And if we may truſt credible ſtory, it hath been frequently attempted not without ſome ſucceſs. So the ancient Britiſh Bladuds.

'Tis

'Tis related of a certain English Monk called *Elmerus*, about the Confessors time, that he did by such wings fly from a Tower above a furlong; and so another from Saint *Marks* steeple in *Venice*; another at *Noninberge*; and *Busbequius* speaks of a Turk in *Constantinople*, who attempted something this way. Mr. *Burton* mentioning this quotation, doth believe that some new-fangled wit ('tis his Cynical phrase) will some time or other find out this art. Though the truth is, most of these Artists did unfortunately miscarry by falling down and breaking their arms or legs, yet that may be imputed to their want of experience, and too much fear, which must needs possess men in such dangerous and strange attempts. Those things that seem very difficult and fearful at the first, may grow very facil after frequent trial and exercise. And therefore he that would effect any thing in this kind, must be brought up to the constant practise of it from his youth. Trying

Ernestus Burgravius in Panoplia Physico Vulcania. Stermius in Lat. lingua resolut.

Melancholy, Part. 2. Sect. 1. Mem. 3.

ing first only to use his wings in running on the ground, as an Ostrich or tame Geese will do, touching the earth with his toes; and so by degrees learn to rise higher, till he shall attain unto skill and confidence. I have heard it from credible testimony, that one of our own Nation hath proceeded so far in this experiment, that he was able by the help of wings in such a running pace, to step constantly ten yards at a time.

It is not more incredible that frequent practise and custom should inable a man for this, then for many other things which we see confirmed by experience. What strange agility and activeness do our common tumblers and dancers on the rope attain to by continual exercise? It is related of certain Indians, that they are able when a horse is running in his full career, to stand upright on his back, to turn themselves round, to leap down, gathering up any thing from the ground, and immediatly to leap up again, to shoot exactly at any mark, the horse not intermitting

Maffæus Hist. Ind. l. 1.

mitting his course. And so upon two horses together, the man setting one of his feet upon each of them. These things may seem impossible to others, and it would be very dangerous for any one to attempt them, who hath not first gradually attained to these arts, by long practise and trial; and why may not such practise enable him as well for this other experiment, as for these things?

There are others who have invented wayes, to walk upon the water, as regularly and as firmly upon the land. There are some so accustomed to this element, that it hath been almost as natural to them, as to the fish; men that could remain for above an hour together under water. *Pontanus* mentions one who could swim above a hundred miles together, from one shore to another, with great speed, and at all times of the year. And it is storied of a certain young man, a *Sicilian* by birth, and a *Diver* by profession, who had so continually used himself to the water, that he could not

Treatise of custom.

not enjoy his health out of it. If at any time he ſtaid with his friends on the land, he ſhould be ſo tormented with a pain in his ſtomack, that he was forced for his health to return back again to Sea, wherein he kept his uſual reſidence; and when he ſaw any ſhips, his cuſtom was to ſwim to them for relief, which kind of life he continued till he was an old man, and dyed.

I mention theſe things to ſhew the great power of practiſe and cuſtom, which might more probably ſucceed in this experiment of flying (if it were but regularly attempted) than in ſuch ſtrange effects as theſe.

It is a uſual practiſe in theſe times, for our *Funambuloes*, or Dancers on the Rope, to attempt ſomewhat like to flying, when they will with their heads forwards ſlide down a long cord extended; being faſtned at one end on the top of ſome high Tower, and the other at ſome diſtance on the ground, with wings fixed to their ſhoulders, by the ſhaking of which they

they will break the force of their descent. It would seem that some attempts of this kind were usual amongst the *Romans*. To which that expression in * *Salvian* may refer, where amongst other publick shews of the Theater, he mentions the *Petaminarii*; which word (saith *Jo. Brassicanus*) is scarce to be found in any other Author, being not mentioned either in *Julius Pollux*, or *Politian*. 'Tis probably derived from the Greek word πέτομαι, which signifies to fly, and may refer to such kind of Rope-dancers.

* *De gube. Dei. l. 6.*

Annot. in Salvi.

But now because the arms extended, are but weak and easily wearied, therefore the motions by them are like to be but short and slow, answerable it may be to the flight of such domestick fowl, as are most conversant on the ground, which of themselves we see are quickly weary, and therefore much more would the arm of a man, as being not naturally designed to such a motion.

It were therefore worth the inqui-

ry

ry to consider whether this might not be more probably effected by the labour of the feet, which are naturally more strong and indefatigable? In which contrivance the wings should come down from the shoulders on each side as in the other, but the motion of them should be from the legs, being thrust out and drawn in again one after another, so as each leg should move both wings, by which means a man should (as it were) walk or climb up into the air: and then the hands and arms might be at leisure to help and direct the motion, or for any other service proportionable to their strength. Which conjecture is not without good probability; and some special advantages above the other.

4. But the fourth and last way seems unto me altogether as probable, and much more useful than any of the rest: And that is by a flying chariot, which may be so contrived as to carry a man within it, and (though the strength of a single man might pro-

haps be ſerviceable for the motion of this engine, yet it were better to have it aſſiſted by the labour of ſome intelligent mover, as the heavenly Orbs are ſuppoſed to be turned. And therefore if it were made big enough to carry ſundry perſons together, then each of them in their ſeveral turns might ſucceſſively labour in the cauſing of this motion; which thereby would be much more conſtant and laſting, than it could otherwiſe be, if it did wholly depend on the ſtrength of the ſame perſon. This contrivance being as much to be preferred before any of the other, as ſwimming in a ſhip before ſwimming in the water.

CAP. VIII.

A reſolution of the two chief difficulties that ſeem to oppoſe the poſſibility of a flying Chariot.

THE chief difficulties againſt the poſſibility of any ſuch contrivance, may be fully removed in the reſolution

ſolution of theſe two *Queries*.

1. Whether an engine of ſuch capacity and weight, may be ſupported by ſo thin and light a body as the air?

2. Whether the ſtrength of the perſons within it, may be ſufficient for the motion of it?

1. Concerning the firſt; when *Callias* was required by the men of *Rhodes*, to take up that great *Helepolis*, brought againſt them by *Demetrius*, (as he had done before unto ſome leſs, which he himſelf had made) He anſwered, that it could not be done. *Nonnulla enim ſunt quæ in exemplaribus videntur ſimilia, cum autem creſcere cœperunt, dilabuntur.* Becauſe thoſe things that appear probable in leſſer models, when they are encreaſed to a greater proportion, do thereby exceed the power of art. For example, though a man may make an inſtrument to bore a hole an inch wide, or half an inch, and ſo leſs; yet to bore a hole of a foot wide, or two foot, is not ſo much as to be

Vitruvius Archit. l. 10. c. 22.

So *Pappus Schol. Mathem. l. 4.*

thought of. Thus, though the air may be able to uphold ſome leſſer bodies, as thoſe of birds; yet when the quantity of them is encreaſed to any great extenſion, it may juſtly be doubted, whether they will not exceed the proportion that is naturally required unto ſuch kind of bodies.

To this I anſwer, That the engine can never be too big or too heavy, if the ſpace which it poſſeſſes in the air, and the motive-faculty in the inſtrument be anſwerable to its weight. That ſaying of *Callias* was but a groundleſs ſhift and evaſion, whereby he did endeavour to palliate his own ignorance and diſability. The utmoſt truth which ſeems to be implied in it, is this: That there may be ſome bodies of ſo great a bigneſs, and gravity, that it is very difficult to apply ſo much force unto any particular inſtrument, as ſhall be able to move them.

Againſt the example, it may be affirmed and eaſily proved, that it is equally poſſible to bore a hole of any bigneſs,

bigneſs, as well great as little, if we ſuppoſe the inſtrument, and the ſtrength, and the application of this ſtrength to be proportionable; But becauſe of the difficulty of theſe concurrent circumſtances in thoſe greater and more unuſual operations, therefore do they falſly ſeem to be abſolutely impoſſible.

So that the chief inference from this argument and example, doth imply only thus much, that it is very difficult to contrive any ſuch motive power, as ſhall be anſwerable to the greatneſs and weight of ſuch an inſtrument as is here diſcourſed of, which doth not at all impair the truth to be maintained; For if the poſſibility of ſuch a motion be yeilded, we need not make any ſcruple of granting the difficulty of it; It is this muſt add a glory to the invention; and yet this will not perhaps ſeem ſo very difficult to any one who hath but diligently obſerved the flight of ſome other birds, particularly of a Kite, how he will ſwim up and down

in the air, ſometimes at a great height, and preſently again lower, guiding himſelf by his train, with his wings extended without any ſenſible motion of them; and all this when there is only ſome gentle breath of air ſtirring, without the help of any ſtrong forcible wind. Now I ſay, if that fowl (which is none of the lighteſt) can ſo very eaſily move it ſelf up and down in the air, without ſo much as ſtirring the wings of it; certainly then, it is not improbable, but that when all the due proportions in ſuch an engine are found out, and when men by long practiſe have arrived to any skill and experience, they will be able in this (as well as in many other things) to come very near unto the imitation of nature.

Sen. Nat. Qu. l. 3. c. 25. As it is in thoſe bodies which are carried on the water, though they be never ſo big, or ſo ponderous, (ſuppoſe equal to a City or a whole Iſland) yet they will always ſwim on the top, if they be but any thing lighter than ſo much water as

as is equal to them in bigneſs: So likewiſe is it in the bodies that are carried in the air. It is not their greatneſs (though never ſo immenſe) that can hinder their being ſupported in that light element, if we ſuppoſe them to be extended unto a proportionable ſpace of air. And as from the former experiments, *Archimedes* hath compoſed a ſubtil *ſcience* in his Book, *De inſidentibus humido*, concerning the weight of any heavy body, in reference to the water wherein it is: So from the particular trial of theſe other experiments, that are here inquired after, it is poſſible to raiſe a new ſcience, concerning the extenſion of bodies, in compariſon to the air, and motive faculties by which they are to be carried.

We ſee a great difference betwixt the ſeveral quantities of ſuch bodies as are commonly upheld by the air; not only little gnats, and flies, but alſo the Eagle and other fowl of vaſter magnitude. *Cardan* and *Scaliger* do unanimouſly affirm, that there is a bird *Subtil. l. 10 Exercit. 231.*

bird amongst the *Indians* of so great a bigness, that his beak is often used to make a sheath or scabbard for a sword. And *Acosta* tells us of a fowl in *Peru* called *Condores*, which will of themselves kill and eat up a whole Calf at a time. Nor is there any reason why any other body may not be supported and carried by the air, though it should as much exceed the quantity of these fowl, as they do the quantity of a fly.

Hist. Nov. Orb. l. 4. c. 37.

Marcus Polus mentions a fowl in *Madagascar*, which he calls a *Ruck*, the feathers of whose wings are 12 paces, or threescore foot long, which can with as much ease coop up an Elephant, as our Kites do a Mouse. If this relation were any thing credible, it might serve as an abundant proof for the present quary. But I conceive this to be already so evident, that it needs not any fable for its further confirmation.

2. The other doubt was, whether the strength of the other persons within it, will be sufficient for the moving

moving of this engine? I answer, the main difficulty and labour of it will be in the raising of it from the ground; near unto which, the earths attractive vigor is of greatest efficacy. But for the better effecting of this, it may be helped by the strength of winds, and by taking its first rise from some mountain, or other high place. When once it is aloft in the air, the motion of it will be easie, as it is in the flight of all kind of birds, which being at any great distance from the earth, are able to continue their motion for a long time and way, with little labour or weariness.

It is certain from common relation and experience, that many birds do cross the seas for divers hundred miles together: sundry of them amongst us, which are of a short wing and flight, as Blackbirds, Nightingales, &c. do fly from us into *Germany*, and other remoter Countries. And Mariners do commonly affirm, that they have found some fowl above six hundred miles from any land. *Plin. l. 10, c. 23.*

Now

Now if we ſhould ſuppoſe theſe birds to labour ſo much in thoſe long journeys, as they do when they fly in our ſight, and near the earth, it were impoſſible for any of them to paſs ſo far without reſting. And therefore it is probable, that they do mount unto ſo high a place in the air, where the natural heavineſs of their bodies does prove but little or no impediment to their flight; Though perhaps either hunger, or the ſight of ſhips, or the like accident, may ſometimes occaſion their deſcending lower, as we may gheſs of thoſe birds, which Mariners have thus beheld; and divers others, that have been drowned and caſt up by the ſea.

Whence it may appear, that the motion of this Chariot (though it may be difficult at the firſt) yet will ſtill be eaſier, as it aſcends higher, till at length it ſhall become utterly devoid of gravity, when the leaſt ſtrength will be able to beſtow upon it a ſwift motion; as I have proved more

more at large in another diſcourſe.

World in the Moon, c. 14.

But then, (may ſome object) if it be ſuppoſed that a man in the æthereal air does loſe his own heavineſs, how ſhall he contribute any force towards the motion of this inſtrument?

I anſwer, The ſtrength of any living creature in theſe external motions, is ſomething really diſtinct from, and ſuperadded unto its naturally gravity: as common experience may ſhew, not only in the impreſſion of blows or violent motions, as a River-hawk will ſtrike a fowl with a far greater force, than the meer deſcent or heavineſs of his body could poſſibly perform: But alſo in thoſe actions which are done without ſuch help, as the pinching of the finger, the biting of the teeth, &c. all which are of much greater ſtrength than can proceed from the meer heavineſs of thoſe parts.

As for the other particular doubts, concerning the extreme thinneſs and coldneſs of this æthereal air, by reaſon of which it may ſeem to be al-

altogether impassible, I have already resolved them in the above-cited discourse.

The uses of such a Chariot may be various: Besides the discoveries which might be thereby made in the Lunary world; It would be serviceable also for the conveyance of a man to any remote place of this earth: as suppose to the *Indies* or *Antipodes*. For when once it was elevated for some few miles, so as to be above that Orb of Magnetick virtue, which is carried about by the earths diurnal revolution, it might then be very easily and speedily directed to any particular place of this great Globe.

If the place which we intended were under the same parallel, why then the earths revolution once in twenty-four hours, would bring it to be under us, so that it would be but descending in a straight line, and we might presently be there. If it were under any other parallel, it would then only require that we should direct it in the same Meridian, till we did come to that paral-

parallel; and then (as before) a man might easily descend unto it.

It would be one great advantage in this kind of travelling, that one should be perfectly freed from all inconveniences of ways or weather, not having any extremity of heat, or cold, or Tempests to molest him: This æthereal air being perpetually in an equal temper and calmness. *Pars superior mundi ordinatior est nec in nubem cogitur, nec in tempestatem impellitur, nec versatur in turbinem, omni tumultu caret, inferiora fulminant.* The upper parts of the world are always quiet and serene, no winds and blustring there; they are these lower cloudy regions that are so full of tempests and combustion.

Sen. de Ira L. 3. c. 6. Patem summa tenuens, Lucan.

As for the manner how the force of a spring, or (instead of that) the strength of any living person, may be applied to the motion of these wings of the Chariot, it may easily be apprehended from what was formerly delivered.

There are divers other particulars to

to be more fully enquired after, for the perfecting of ſuch a flying Chariot; as concerning the proportion of the wings both for their length and breadth, in compariſon to the weight which is to be carried by them, as alſo concerning thoſe ſpecial contrivances, whereby the ſtrength of theſe wings may be ſeverally applied either to aſcent, deſcent, progreſſive, or a turning motion; All which, and divers the like enquiries can only be reſolved by particular experiments. We know the invention of ſailing in ſhips does continually receive ſome new addition from the experience of every age, and hath been a long while growing up to that perfection, unto which it is now arrived. And ſo muſt it be expected for this likewiſe, which may at firſt perhaps ſeem perplexed with many difficulties and inconveniencies, and yet upon the experience of frequent tryals, many things may be ſuggeſted to make it more facil and commodious.

As well too long as too ſhort, too broad as too narrow, may be an impediment to the motion, by making it more difficult, ſlow and flagging.

He

He that would regularly attempt any thing to this purpose, should observe this progress in his experiments, he should first make enquiry what kind of wings would be most useful to this end; those of a Bat being most easily imitable, and perhaps nature did by them purposely intend some intimation to direct us in such experiments; that creature being not properly a bird, because not amongst the *Oviparæ*, to imply that other kind of creatures are capable of flying as well as birds; and if any should attempt it, that would be the best pattern for imitation.

After this he might try what may be effected by the force of springs in lesser models, answerable unto *Archytas* his Dove, and *Regiomontanus* his Eagle: In which he must be careful to observe the various proportions betwixt the strength of the spring, the heavines of the body, the breadth of the wings, the swiftnes of the motion, &c.

From these he may by degrees ascend to some larger essays. CAP.

CHAP. IX.

Of a perpetual motion. The seeming facility and real difficulty of any such contrivance. The several wayes whereby it hath been attempted, particularly by Chymistry.

IT is the chief inconvenience of all the *Automata* before mentioned, that they need a frequent repair of new strength; the causes whence their motion does proceed, being subject to fail and come to a period; and therefore it would be worth our enquiry, to examine, whether or no there may be made any such artificial contrivance, which might have the principle of moving from it self; so that the present motion should constantly be the cause of that which succeeds.

This is that great Secret in *Art*, which like the Philosophers Stone in *Nature*, hath been the business and study of many more refined Wits, for divers ages together; and it may well be questioned, whether either of

of them as yet, hath ever been found out, though if this have, yet like the other, it is not plainly treated of by any Author.

Not but that there are ſundry diſcourſes concerning this ſubject, but they are rather *conjectures* than *experiments*. And though many inventions in this kind, may at firſt view bear a great ſhew of probability, yet they will fail, being brought to trial, and will not anſwer in practiſe what they promiſed in ſpeculation. Any one who hath been verſed in theſe experiments muſt needs acknowledge that he hath been often deceived in his ſtrongeſt confidence; when the imagination hath contrived the whole frame of ſuch an inſtrument, and conceives that the event muſt fallibly anſwer its hopes; yet then does it ſtrangely deceive in the proof, and diſcovers to us ſome defect, which we did not before take notice of.

Hence it is, that you ſhall ſcarce talk with any one who hath never ſo little ſmattering in theſe arts, but he

will instantly promise such a motion, as being but an easie atchievement, till further trial and experience hath taught him the difficulty of it. There being no enquiry that does more entice with the *probability*, and deceive with the *subtilty*. What one speaks wittily concerning the Philosophers Stone, may be justly applyed to this, that it is *Casta meretrix*, a chaste Whore, *Quia multos invitat, neminem admittit*, because it allures many, but admits none.

I shall briefly recite the several ways whereby this hath been attempted, or seems most likely to be effected, thereby to contract and facilitate the enquiries of those who are addicted to these kind of experiments; for when they know the defects of other inventions, they may the more easily avoid the same, or the like, in their own.

The ways whereby this hath been attempted, may be generally reduced to these three kinds:

1. By Chymical extractions.

2. By

2. By Magnetical virtues.

3. By the natural affection of gravity.

1. The diſcovery of this hath been attempted by Chymiſtry. *Paracelſus* and his followers have bragged, that by their ſeparations and extractions, they can make a little world which ſhall have the ſame perpetual motions with this *Microcoſme*, with the repreſentation of all Meteors, Thunder, Snow, Rain, the courſes of the ſea in its ebbs and flows, and the like; But theſe miraculous promiſes would require as great a faith to belive them, as a power to perform them: And though they often talk of ſuch great matters,

At nuſquam totos inter qui talia curant,
Apparet ullus, qui re miracula tanta
Comprobet—

yet we can never ſee them confirmed by any real experiment; and then beſides, every particular Author in that art, hath ſuch a diſtinct language of his own, (all of them being ſo full

of allegories and affected obſcurities) that 'tis very hard for any one (unleſs he be throughly verſed amongſt them) to find out what they mean, much more to try it.

Etten Mathem. Recreat. prob. 118.

One of theſe ways (as I find it ſet down) is this. Mix five ounces of ☿, with an equal weight of ♄, grind them together with ten ounces of ſublimate, diſſolve them in a Cellar upon ſome marble for the ſpace of four dayes, till they become like oyl-olive; diſtil this with fire of chaff, or driving fire, and it will ſublime into a dry ſubſtance: and ſo by repeating of theſe diſſolvings and diſtillings, there will be at length produced divers ſmall atomes, which being put into a glaſs well luted, and kept dry, will have a perpetual motion.

I cannot ſay any thing from experience againſt this; but methinks it does not ſeem very probable, becauſe things that are forced up to ſuch a vigorouſneſs and activity, as theſe ingredients ſeem to be by their frequent

quent ſublimatings and diſtillings, are not likely to be of any duration; the more any thing is ſtretched beyond its uſual nature, the leſs does it laſt, violence and perpetuity being no companions. And then beſides, ſuppoſe it true, yet ſuch a motion could not well be applied to any uſe, which muſt needs take much from the delight of it.

Amongſt the Chymical experiments to this purpoſe may be reckoned up that famous motion invented by *Cornelius Dreble*, and made for King *James*; wherein was repreſented the conſtant revolutions of the Sun and Moon, and that without the help either of ſpring or weights. *Marcellus Vranckhein*, ſpeaking of the means whereby it was performed, he calls it, *Scintillula animæ magneticæ mundi, ſeu Aſtralis & inſenſibilis ſpiritus*; being that grand ſecret, for the diſcovery of which, thoſe Dictators of Philoſophy, *Democritus*, *Pythagoras*, *Plato*, did travel unto the Gymnoſophiſts, and *Indian* Prieſts.

Celebrated in an Epigram by *Hugo Grotius* l. *Epi. Epiſt. ad Erneſtum de Lamp. Vitæ.*

Epiſt. ad Jacobum Regem.

The Author himſelf in his diſcourſe upon it, does not at all reveal the way, how it was performed. But there is one *Thomas Tymme*, who was a familiar acquaintance of his, and did often pry into his works, (as he profeſſes himſelf) who affirms it to be done thus; *By extracting a fiery ſpirit out of the Mineral matter, joyning the ſame with his proper air, which included in the Axle-tree* (of the firſt moving wheel) *being hollow, carrieth the other wheels, making a continual rotation, except iſſue or vent be given in this hollow axle-tree, whereby the impriſoned ſprit may get forth.*

Philoſophical dialogue. *Confer.* 2. *cap.* 3.

What ſtrange things may be done by ſuch extractions, I know not, and therefore dare not condemn this relation as is impoſſible; but me thinks it ſounds rather like a chymical dream, than a Philoſophical truth. It ſeems this impriſoned ſpirit is now ſet at liberty, or elſe is grown weary, for the inſtrument (as I have heard) hath ſtood ſtill for many years. It is here conſiderable, that any force is weakeſt near

near the center of a wheel; and therefore though such a spirit might of it self have an agitation, yet 'tis not easily conceivable how it should have strength enough to carry the wheels about with it. And then the absurdity of the Authors citing this, would make one mistrust his mistake; he urges it as a strong argument against *Copernicus*, as if because *Drebel* did thus contrive in an Engine, the revolution of the heavens, and the immovableness of the earth, therefore it must needs follow, that 'tis the heavens which are moved, and not the earth. If his relation were no truer than his consequence, it had not been worth the citing.

CAP. X.

Of ſubterraneous lamps: divers hiſtorical relations concerning their duration for many hundred years together.

UNto this kind of Chymical experiments, we may moſt probably reduce thoſe perpetual lamps, which for many hundred years together have continued burning without any new ſupply in the ſepulchres of the Ancients, and might (for ought we know) have remained ſo for ever. All fire, and eſpecially flame, being of an active and ſtirring nature, it cannot therefore ſubſiſt without motion; whence it may ſeem, that this great enquiry hath been this way accompliſhed: And therefore it will be worth our examination to ſearch further into the particulars that concern this experiment. Though it be not ſo proper to the chief purpoſe of this diſcourſe, which concerns *Mechanical Geometry*, yet the ſubtilty and

and curiosity of it, may abundantly requite the impertinency.

There are sundry Authors who treat of this Subjection the by, and in some particular passages, but none that I know of (except *Fortunius Licetus*) that hath writ purposely any set and large discourse concerning it: out of whom I shall borrow many of those relations and opinions, which may most naturally conduce to the present enquiry.

Lib. de reconditis antiquorum lucernis.

For our fuller understanding of this, there are these particulars to be explained:

1. ὅτι, or *quod sit.*
2. διότι { *cur sit.* / *quomodo sit.*

1. First then, for the ὅτι, or that there have been such lamps, it may be evident from sundry plain and undeniable testimonies: Saint *Austin* mentions one of them in a Temple dedicated to *Venus*, which was always exposed to the open weather, and could never be consumed or extinguished. To him assents the judicious

De Civit. Dei. l. 21. cap. 6.

cious *Zanchy*. *Pancyrollus* mentions a Lamp found in his time, in the sepulcher of *Tullia*, *Cicero's* daughter, which had continued there for about 1550 years, but was presently extinguished upon the admission of new air. And 'tis commonly related of *Cedrenus*, that in *Justinians* time there was another burning lamp found in an old wall at *Edessa*, which had remained so for above 500 years, there being a Crucifix placed by it, whence it should seem that they were in use also amongst some Christians.

De operibus Dei part. 1. l. 4. c. 12. Dedeperd. Tit. 35.

*Or *Amioch. Licetus de Lucernis, l. 1. c. 7.*

But more especially remarkable is that relation celebrated by so many Authors, concerning *Olybius*, his lamp, which had continued burning for 1500 years. The story is thus: As a rustick was digging the ground by *Padua*, he found an Urn or earthen pot, in which there was another Urn, and in this lesser, a lamp clearly burning; on each side of it there were two other Vessels, each of them full of a pure liquor, the one of gold, the other of silver. *Ego Chymiæ artis*,

modo vera poteſt eſſe ars Chymia) *jurare auſim elementa & materiam omnium*, (ſaith *Maturantius*, who had the poſſeſſion of theſe things after they were taken up). On the bigger of theſe Urns there was this inſcription:

Plutoni ſacrum munus ne attingite fures.
Ignotum eſt vobis hoc quod in orbe latet,
Namque elementa gravi clauſit digeſta labore
Vaſe ſub hoc modico, Maximus Olybius.
Adſit fœcundo cuſtos ſibi copia cornu,
Ne tanti pretium depereat laticis.

The leſſer Urn was thus inſcribed:

Abite hinc peſſimi fures,
Vos quid vultis, *veſtris cum oculis emiſſitiis?*
Abite hinc veſtro cum Mercurio
Petæſato Caduceatoque,
Donum hoc Maximum, Maximus Olybius
Plutoni ſacrum facit.

Whence we may probably conjecture that it was ſome Chymical ſecret,

cret, by which this was contrived.

Mag. Natural. l. 12. c. ult. *Baptiſta Porta* tells us of another lamp burning in an old marble ſepulcher, belonging to ſome of the ancient *Romans*, incloſed in a glaſs vial, found in his time, about the year 1550, in the Iſle *Neſis*, which had been buried there before our Saviours coming.

Chron. Martin Fort. licet. de lucern. l. 1. c. 11. In the Tomb of *Pallas* the *Arcadian* who was ſlain by *Turnus* in the *Trojan* war, there was found another burning lamp in the year of our Lord 1401. Whence it ſhould ſeem, that it had continued there for above two thouſand and ſix hundred years: and being taken out, it did remain burning, notwithſtanding either wind or water, with which ſome did ſtrive to quench it; nor could it be extinguiſhed till they had ſpilt the liquor that was in it.

Not ad Auguſt. de Civit. Dei, l. 21. c. 6. *Ludovicus Vives* tells us of another lamp that did continue burning for 1050 years, which was found a little before his time.

Such a lamp is likewiſe related to be

be ſeen in the ſepulcher of *Francis Roſicroſs*, as is more largely expreſſed in the confeſſion of that fraternity.

There is another relation of a certain man, who upon occaſion digging ſomewhat deep in the ground, did meet with ſomething like a dore, having a wall on each hand of it; from which having cleared the earth, he forced open the door; upon this there was diſcovered a fair Vault, and towards the farther ſide of it, the ſtatue of a man in Armour, ſiting by a table, leaning upon his left arm, and holding a ſcepter in his right hand, with a lamp burning before him; the floor of this Vault being ſo contrived, that upon the firſt ſtep into it, the ſtatue would erect it ſelf from its leaning poſture; upon the ſecond ſtep it did lift up the ſcepter to ſtrike, and before a man could approach near enough to take hold of the lamp, the ſtatue did ſtrike and break it to pieces; ſuch care was there taken that it might not be ſtoln away, or diſcovered.

Our learned *Cambden* in his deſcrip- *Pag.* 572.
tion

tion of *Yorkshire*, speaking of the tomb of *Constantius Chlorus*, broken up in these later years, mentions such a lamp to be found within it.

There are sundry other relations to this purpose. *Quod ad lucernas attinet, illæ in omnibus fere monumentis inveniuntur*, (saith *Gutherius*). In most of the ancient Monuments there is some kind of lamp, (though of the ordinary sort); But those persons who were of greatest note and wisdom, did procure such as might last without supply, for so many ages together. *Pancirollus* tells us, that it was usual for the Nobles amongst the Romans, to take special care in their last wills, that they might have a lamp in their Monuments. And to this purpose they did usually give liberty unto some of their slaves on this condition, that they should be watchful in maintaining and preserving it. From all which relations, the first particular of this enquiry, concerning the being or existence of such lamps, may sufficiently appear.

De jure manium, l. 2. c. 32.

De perdit. Tit. 62.

CAP.

CAP. XI.

Several opinions concerning the nature and reason of these perpetual Lamps.

There are two opinions to be answered, which do utterly overthrow the chief consequence from these relations.

1. Some think that these lights so often discovered in the ancient tombs, were not fire or flame, but only some of those bright bodies which do usually shine in dark places.

2. Others grant them to be fire, but yet think them to be then first enkindled by the admission of new air, when these sepulchres were opened.

1. There are divers bodies (saith *Aristotle*) which shine in the dark, as rotten wood, the scales of some fishes, stones, the glow-worm, the eyes of divers creatures. *Cardan* tells us of a bird in new *Spain*, called *Cocoyum*, whose whole body is very bright, but his eyes almost equal to the light of

De anim. l. 2. c. 7.

Subtil. l. 9.

a candle, by which alone in a dark night one may both write and read; By these the *Indians* (saith he) use to eat their feasting Suppers.

It is commonly related and believed, that a Carbuncle does shine in the dark like a burning coal, from whence it hath its * name. To which purpose there is a story in *Ælian*, of a Stork, that by a certain woman was cured of a broken thigh, in gratitude to whom, this fowl afterwards flying by her, did let fall into her lap a bright Carbuncle, which (saith he) would in the night time shine as clear as a lamp. But this and the like old relations are now generally disbelieved and rejected by learned men: *Doctissimorum omnium consensu, hujusmodi gemmæ non inveniuntur*, (saith *Boetius de Boot*) a man very much skill'd in, and inquisite after such matters; nor is there any one of name that does from his own eye-sight or experience affirm the real existence of any gem so qualified.

* *Carbo Pyropus Historia Animal. l. 8*

De lapid. & Gemmis. l. 2. c. 8.

Some have thought that the light in

in ancient tombs hath been occasioned from some such bodies as these. For if there had been any possibility to preserve fire so long a space, 'tis likely then that the *Israelites* would have known the way, who were to keep it perpetually for their sacrifices. *Vide Licet. de lucern. l. 2.*

But to this opinion it might be replyed, that none of these *Noctiulæ*, or night-shining bodies have been observed in any of the Ancient sepulchres, and therefore this is a meer imaginary conjecture; And then besides, some of these lamps have been taken out burning, and continued so for a considerable space afterwards. As for the supposed conveniency of them, for the perpetuating of the holy fire amongst the Jews, it may as well be feared lest these should have occasioned their idolatry, unto which that Nation was so strongly addicted upon every slight occasion; nor may it seem strange, if the providence of God should rather permit this fire sometimes to go out, that so by their earnest prayers, being a-

gain renewed from heaven, (as it * ſometimes was) the peoples faith might be the better ſtirred up and ſtrengthned by ſuch frequent miracles.

* Levit. 9. 24. 2 Chron. 7. 1. 1 King. 18. 38.

2. It is the opinion of *Gutherius*, that theſe lamps have not continued burning for ſo long a ſpace as they are ſuppoſed in the former relations; but that they were then firſt enflamed by the admiſſion of new air, or ſuch other occaſion, when the ſepulchres were opened: as we ſee in thoſe fat earthy vapours of divers ſorts, which are oftentimes enkindled into a flame. And 'tis ſaid, that there are ſome Chymical ways, whereby iron may be ſo heated, that being cloſely luted in a glaſs, it ſhall conſtantly retain the fire for any ſpace of time, though it were for a thouſand years or more; at the end of which, if the glaſs be opened, and the freſh air admitted, the iron ſhall be as red hot as if it were newly taken out of the fire.

De jure Mani. l. 2. c. 32.

But for anſwer to this opinion, 'tis conſider[illegible] that ſome Urns have had inſcrip-

inſcriptions on them, expreſſing that the lamps within them were burning, when they were firſt buried. To which may be added the experience of thoſe which have continued ſo for a good ſpace afterwards; whereas the inflamation of fat and viſcous vapours, does preſently vaniſh. The lamp which was found in the Iſle *Neſis*, did burn clearly while it was incloſed in the glaſs; but that being broken, was preſently exſtinguiſhed. As for that Chymical relation, it may rather ſerve to prove, that fire may continue ſo many ages, without conſuming any fuel.

So that notwithſtanding the oppoſite opinions, yet 'tis more probable that there have been ſuch lamps as have *remained burning*, without any new ſupply, for many hundred years together; which was the firſt particular to be explained.

2. Concerning the reaſon, why the Ancients were ſo careful in this particular; there are divers opinions. Some think it to be an expreſſion of *Cur fiat.*

their belief, concering the ſouls immortality, after its departure out of the body, a lamp amongſt the *Egyptians* being the *Hieroglyphick* of life. And therefore they that could not procure ſuch lamps, were yet careful to have the image and repreſentation of them ingraved on their Tombs.

Others conceive them to be by way of gratitude to thoſe infernal Deities, who took the charge and cuſtody of their dead bodies, *remaining* always with them in their Tombs, and were therefore called *Dii manes*.

Others are of opinion, that theſe lamps were only intended to make their ſepulchres more pleaſant and lightſome, that they might not ſeem to be impriſoned in a diſmal and uncomfortale place. True indeed, the dead body cannot be ſenſible of the light, no more could it of its want of burial; yet the ſame inſtinct which did excite it to the deſire of one, did alſo occaſion the other.

De Lucernis, l. 3. c. 8. *Licetus* concludes this ancient cuſtome to have a double end: 1. *Politick*,

litick, for the distinction of such as were nobly born, in whose Monuments only they were used. 2. *Natural*, to preserve the body and soul from darkness; For it was a common opinion amongst them, that the souls also were much conversant about those places where the bodies were buried.

CHAP. XII.

The most probable conjecture how these lamps were framed.

THE greatest difficulty of this enquiry doth consist in this last particular, concerning the manner how, or by what possible means any such perpetual flame may be contrived. *Quomodo fiat.*

For the discovery of which, there are two things to be more especially considered.

1. The snuff or wick, which must administer unto the flame.

2. The oyl, which must nourish it.

For the first, it is generally granted that there are divers substances which will retain fire without consuming: such is that Mineral which they call the Salamanders-wool, saith our learned * *Bacon. Ipse expertus sum villos Salamandræ non consumi*, saith † *Joachimus Fortius.* And * *Wecker* from his own knowledg affirms the same of *plumealium*, that being formed into the likeness of a wick, will administer to the flame, and yet not consume it self. Of this nature likewise was that which the Ancients did call *Linum vivum*, or *Asbestinum;* of this they were wont to make garments that were not destroyed, but purified by fire; and whereas the spots or foulness of other cloaths are washed out, in these they were usually burnt away. The bodies of the ancient Kings were wrapped in such garments when they were put in the funeral-pile, that their ashes might be therein preserved, without the mixture of any other. The materials of them were not from any herb or vegetable,

* *Nat. hist. exper. 774.*
† *Lib. exper.*
* *De Secretis, l. 3. c. 2.*
Or *Linum Carpasium Plutarch. de Oracul. defectu.*
Plin. Hist. l. 19. c. 1.

ble, as other textils, but from a ſtone called *Amiantus*, which being bruiſed by a hammer, and its earthy nature ſhaken out, retains certain hairy ſubſtances, which may be ſpun and woven as hemp or flax. *Pliny* ſays, that for the precioufneſs of it, it did almoſt equal the price of pearls. *Pancirollus* tells us, that it was very rare, and eſteemed precious in ancient times; but now is ſcarce found or known in any place, and therefore he reckons it amongſt the things that are loſt. But *L. Vives* affirms, that he hath often ſeen wieks made of it at *Paris*, and the ſame matter woven into a napkin at *Lovaine*, which was cleanſed by being burnt in the fire.

Deperd. Tit. 4.

In Auguſt. de Civit. Dei l. 21. c. 6.

'Tis probable from theſe various relations, that there was ſeveral ſorts of it, ſome of a more precious, others of a baſer kind, that was found in *Cyprus*, the deſerts of *India*, and a certain Province of *Aſia*: this being common in ſome parts of *Italy*, but is ſo ſhort and brittle, that it cannot be ſpun into a thred. And

therefore is useful only for the wicks of perpetual lamps, saith *Boetius de Boot.* Some of this, or very like it, I have upon inquiry lately procured and experimented. But whether it be the stone *Asbestus*, or only *Plume-allum*, I cannot certainly affirm. For it seems they are both so very like, as to be commonly sold for one another (saith the same Author). However, it does truly agree in this common quality ascribed unto both, of being incombustible, and not consumable by fire: But yet there is this inconvenience, that it doth contract so much fuliginous matter from the earthy parts of the oyl, (though it was tryed with some of the purest oyl, which is ordinary to be bought) that in a very few dayes it did choak and extinguish the flame. There may possibly be some chymical way so to purifie and defecate this oyl, that it shall not spend into a sooty matter.

De lapid. & gemmis, l. 2 c. 204.

However if the liquor be of a close and glutinous consistency, it may burn without any snuff, as we see in

in Camphire, and some other bituminous substances. And it is probable that most of the ancient lamps were of this kind, because the exactest relations (to my remembrance) do not mention any that have been found with such wicks.

But herein will consist the greatest difficulty, to find out what invention there might be for their duration. Concerning which there are sundry opinions.

Saint *Austin* speaking of that Lamp in one of the Heathen Temples, thinks that it might either be done by Magick, the Devil thinking thereby to promote the worship and esteem of that idol to which it was dedicated; or else that the art of man might make it of some such material, as the stone *Asbestus*, which being once enkindled, will burn without being consumed. As others (saith he) have contrived as great a wonder in appearance, from the natural virtue of another stone, making an iron image seem to hang in the air, by rea-

De Civ. Dei l. 21. c. 6.

Zanch. de Operibus Dei, par. 1. l. 4. c. 12.

reaſon of two load-ſtones, the one being placed in the Cieling, the other in the floor.

Others are of opinion, that this may be effected in a hollow veſſel, exactly luted or ſtopped up in all the vents of it. And then, if a lamp be ſuppoſed to burn in it, but for the leaſt moment of time, it muſt continue ſo always, or elſe there would be a *Vacuum*, which nature is not capable of; If you ask, how it ſhall be nouriſhed, it is anſwered, that the oyl of it being turned into ſmoak and vapours, will again be converted into its former nature; For otherwiſe, if it ſhould remain rarified in ſo thin a ſubſtance, then there would not be room enough for that fume which muſt ſucceed it; and ſo on the other ſide, there might be ſome danger of the *Penetration* of bodies, which nature doth as much abhor. To prevent both which, as it is in the Chymical circulations, where the ſame body is oftentimes turned from liquor into vapour, and from vapour into liquor again; ſo in

in this experiment, the ſame oyl ſhall be turned into fume, and that fume ſhall again convert into oyl. Always provided, that this oyl which nouriſhes the lamp, be ſuppoſed of ſo cloſe and tenacious a ſubſtance, that may ſlowly evaporate, and ſo there will be the more leiſure for nature to perfect theſe circulations. According to which contrivance, the lamp within this veſſel can never fail, being always ſupplyed with ſufficient nouriſhment. That which was found in the Iſle *Neſis*, incloſed in a glaſs vial, mentioned by *Baptiſta Porta*, is thought to be made after ſome ſuch manner as this.

Others conceive it poſſible to extract ſuch an oyl out of ſome Minerals, which ſhall for a long ſpace ſerve to nouriſh the flame of a lamp with very little or no expence of its own ſubſtance. To which purpoſe (ſay they) if gold be diſſolved into an unctuous humour; or if the radical moiſture of that metal were ſeparated, it might be contrived to burn (perhaps

Wolphang Lazius, l. 3. c. 18. Camb. Brit. p. 572.

(perhaps for ever, or at leaſt) for many ages together, without being conſumed. For if gold it ſelf (as experience ſhews) be ſo untameable by the fire, that after many meltings, and violent heats, it does ſcarce diminiſh; 'tis probable then, that being diſſolved into an oylie ſubſtance, it might for many hundred years together continue burning.

There is a little Chymical diſcourſe, to prove that *Urim* and *Thummim* is to be made by art; the Author of this Treatiſe affirms that place, *Gen.* 6. 16. where God tells *Noah*, *a window ſhalt thou make in the Ark*, to be very unfitly rendered in our Tranſlation a window, becauſe the Original word צהר ſignifies properly ſplendor or light; and then beſides, the air being at that time ſo extremely darkned with the clouds of that exceſſive rain, a window could be but of very little uſe in regard of light, unleſs there were ſome other help for it; from whence he conjectures that both this ſplendor, and ſo likewiſe the Urim

and

and Thummim, were artificial Chymical preparations of light, answerable to these subterraneous lamps; or in his own phrase, it hath *the universal spirit fixed in a transparent body.*

It is the opinion of *Licetus* (who hath more axactly searched into the subtilties of this enquiry) that fire does not need any humour for the nourishment of it, but only to detain it from flying upwards. For being it self one of the chief elements (saith he out of *Theophrastus*) it were absurd to think that it could not subsist without something to feed it. As for that substance which is consumed by it, this cannot be said to foment or preserve the same fire, but only to generate new. For the better understanding of this, we must observe, that there may be a threefold proportion betwixt fire, and the humour or matter of it. Either the humour does exceed the strength of the fire, or the fire does exceed the humour; and according to both these, the flame doth presently vanish. Or

De Lucernis, c. 20. 21.

else

elſe laſtly, they may be both equal in their virtues, (as it is betwixt the radical moiſture and natural heat in living creatures) and then neither of them can overcome or deſtroy the other.

Thoſe ancient lamps of ſuch long duration, were of this later kind. But now, becauſe the qualities of heat or cold, dryneſs or moiſture in the ambient air, may alter this equality of proportion betwixt them, and make one ſtronger than the other; therefore to prevent this, the Ancients did hide theſe lamps in ſome caverns of the earth, or cloſe monuments: And hence is it, that at the opening of theſe, the admiſſion of new air unto the lamp does uſually cauſe ſo great an inequality betwixt the flame and the oyl, that it is preſently extinguiſhed.

But ſtill the greateſt difficulty remains, how to make any ſuch exact proportion betwixt an unctuous humour, and ſuch an active quality, as the heat of fire; or this equality being

ing made, it is yet a further difficulty, how it may be preſerved. To which purpoſe, *Licetus* thinks it poſſible to extract an inflameable oyl from the ſtone *Aſbeſtus*, *Amiantus*, or the metal Gold, which being of the ſame pure and homogeneous nature with thoſe bodies, ſhall be ſo proportioned unto the heat of fire, that it cannot be conſumed by it, but being once inflamed ſhould continue for many ages, without any ſenſible diminution.

If it be in the power of Chymiſtry to perform ſuch ſtrange effects as are commonly experimented in that which they call *aurum fulminans*, one ſcruple of which ſhall give a lowder blow, and be of greater force in deſcent, than half a pound of ordinary Gunpowder in aſcent; why may it not be as feaſible by the ſame art to extract ſuch an oyl as is here enquired after: ſince it muſt needs be more difficult to make a fire which of its own inclination ſhall tend downwards, than to conrrive ſuch an unctuous

ctuous liquor, wherein fire ſhall be maintained for many years without any new ſupply?

Thus have I briefly ſet down the relations and opinions of divers learned men concerning theſe perpetual lamps; of which, though there have been ſo many ſundry kinds, and ſeveral ways to make them, (ſome being able to reſiſt any violence of weathers, others being eaſily extinguiſhed by any little alteration of the air; ſome being incloſed round about within glaſs, others being open); yet now they are all of them utterly periſhed amongſt the other ruines of time; and thoſe who are moſt verſed in the ſearch after them, have only recovered ſuch dark conjectures, from which a man cannot clearly reduce any evident principle that may encourage him to a particular trial.

CAP.

CAP. XIII.

Concerning ſeveral attempts of contriving a perpetual motion by Magnetical virtues.

THE ſecond way whereby the making of a perpetual motion hath been attempted, is by Magnetical virtues; which are not without ſome ſtrong probabilities of proving effectual to this purpoſe: eſpecially when we conſider that the heavenly revolutions, (being as the firſt pattern imitated and aimed at in theſe attempts) are all of them performed by the help of theſe qualities. This great Orb of earth, and all the other Planets being but as ſo many Magnetical Globes endowed with ſuch various and continual motions, as may be moſt agreable to the purpoſes for which they were intended. And therefore moſt of the Authors who treat concerning this invention, do agree, that the likelieſt way to effect it, is by theſe kind of qualities.

It was the opinion of *Pet. Peregrinus*, and there is an example pretended for it in *Bettinus* (*Apiar. 9. Progym. 5. pro.* 11.) That a Magnetical Globe or Terella, being rightly placed upon its poles, would of it self have a constant rotation, like the diurnal motion of the earth; But this is commonly exploded, as being against all experience.

Gilbert. de Magnet. Calæus Philos. Magnet. l. 4. c. 20.

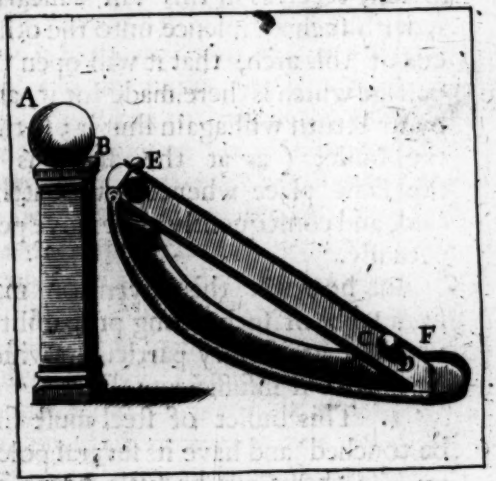
Others think it possible, so to contrive several pieces of steel, and a loadstone, that by their continual attraction and expulsion of one another, they may cause a perpetual revolution of a wheel; Of this opinion were [a] *Taisner* [b] *Pet. Peregrinus*, and [c] *Cardan*, out of *Antonius de Fantis*. But D. *Gilbert*, who was more especially versed in Magnetical experiments, concludes it to be a vain and groundless fancy.

Athanas. Kircher. de Arte Magnet. l. 1. par. 2. prop. 13. p. 4.

a *Tract. de motu continuo.*
b *De Rotis perpetui motus. par. 2. c. 3.*
c *De Variet. rerum. l. 9. c. 48.*
De magnet. l. 2. c. 35.

But amongst all these kind of inventions, that is most likely, wherein a loadstone is so disposed, that it shall draw unto it on a reclined plane, a bullet of steel; which steel, as it ascend

ſcends near to the loadſtone, may be contrived to fall down through ſome hole in the plane, and ſo to return unto the place from whence at firſt it began to move; and being there, the loadſtone will again attract it upwards, till coming to this hole it will fall down again: and ſo the motion ſhall be perpetual, as may be more eaſily conceivable by this figure.



Suppoſe the loadſtone to be repreſented at *A B*, which though it have not ſtrength enough to attract the bullet *C*, directly from the ground, yet may do it by the help of the plane *E F*. Now when the bullet is come to the top of this plane, its own gravity (which is ſuppoſed to exceed the ſtrength of the loadſtone) will make it fall into that hole at *E*: and the force it receives in this fall will carry it with ſuch a violence unto the other end of this arch, that it will open the paſſage which is there made for it, and by its return will again ſhut it; ſo that the bullet (as at the firſt) is in the ſame place whence it was attracted, and conſequently muſt move perpetually.

But however this invention may ſeem to be of ſuch ſtrong probability, yet there are ſundry particulars which may prove it inſufficient; For,

1. This bullet of ſteel muſt firſt be touched and have its ſeveral poles, or elſe there can be little or no attraction of it. Suppoſe *C* in the ſteel

to

to be anſwerable unto *A* in the ſtone, and to *B*; In the attraction, *C D* muſt always be directed anſwerable to *A B*, and ſo the motion will be more difficult, by reaſon there can be no rotation or turning round of the bullet, but it muſt ſlide up with the line *C D*, anſwerable to the axis *A B*.

2. In its fall from *E* to *G*, which is *motus elementaris*, and proceeds from its gravity, there muſt needs be a rotation of it, and ſo 'tis odds but it happens wrong in the riſe, the poles in the bullet being not in the ſame direction to thoſe in the magnet; and if in this reflux it ſhould ſo fall out, that *D* ſhould be directed towards *B*, there ſhould be rather a flight than an attraction, ſince thoſe two ends do *repell* and not draw one another.

3. If the loadſtone *A B*, have ſo much ſtrength that it can attract the bullet in *F*, when it is not turned round, but does only ſlide upon the plane, whereas its own gravity would roul it downwards: then it is evident,

the ſphere of its activity and ſtrength would be ſo increaſed when it approaches much nearer, that it would not need the aſſiſtance of the plane, but would draw it immediately to it ſelf without that help, and ſo the bullet would not fall down through the hole, but aſcend to the ſtone, and conſequently ceaſe its motion. For if the loadſtone be of force enough to draw the bullet on the plane, at the diſtance *F B*, then muſt the ſtrength of it be ſufficient to attract it immediatly unto it ſelf, when it is ſo much nearer as *E B*. And if the gravity of the bullet be ſuppoſed ſo much to exceed the ſtrength of the Magnet, that it cannot draw it directly when it is ſo near, then will it not be able to attract the bullet up the plane, when it is ſo much further off.

So that none of all theſe Magnetical experiments, which have been as yet diſco-ed, are ſufficient for the effecting of a perpetual motion, though theſe kind of qualities ſeem moſt conducible unto it, and perhaps

haps hereafter it may be contrived from them.

CAP. XIV.

The ſeeming probability of effecting a continual motion by ſolid weights in a hollow wheel or ſphere.

THE third way whereby the making of a perpetual motion hath been attempted, is by the natural affection of gravity; when the heavineſs of ſeveral bodies is ſo contrived, that the ſame motion which they give in their deſcent, may be able to carry them up again.

But againſt the poſſibility of any ſuch invention, it is thus objected by *Cardan*; All ſublunary bodies have a direct motion either of aſcent or deſcent; which, becauſe it does refer to ſome term, therefore cannot be perpetual, but muſt needs ceaſe when it is arrived at the place unto which it naturally tends. *Subtil. l. 17 De Var. Rerum. l. 9 c. 48.*

I anſwer, though this may prove

that there is no natural motion of any particular heavy body, which is perpetual; yet it doth not hinder but that is is possible from them to contrive such an artificial revolution as shall constantly be the cause of it self.

Those bodies which may be serviceable to this purpose, are distinguishable into two kinds.

1. Solid and consistent, as weights of metal, or the like.

2. Fluid or sliding, as water, sand, &c.

Both these ways have been attempted by many, though with very little or no success. Other mens conjectures in this kind you may see set down by divers Authors. It would be too tedious to repeat them over, or set forth their draughts. I shall only mention two news ones, which (if I am not over partial) seem altogether as probable as any of these kinds that have been yet invented; and till experience had discovered their defect and insufficiency, I did certainly

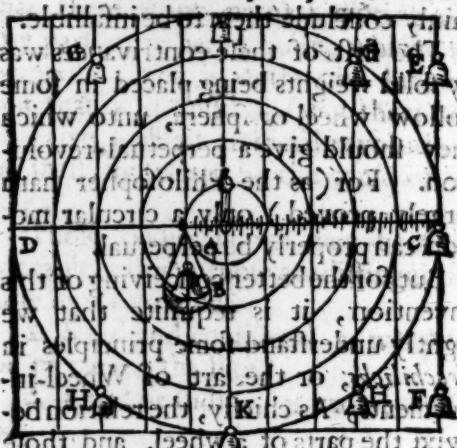
D. Flud. Tract. 1. part 7. l. 2. c. 4. & 7.

tainly conclude them to be infallible.

The firſt of theſe contrivances was by ſolid weights being placed in ſome hollow wheel or ſphere, unto which they ſhould give a perpetual revolution. For (as the Philoſopher hath largely proved) only a circular motion can properly be perpetual. *Ariſt. Phiſ. l. 8, c. 12.*

But for the better conceiving of this invention, it is requiſite that we rightly underſtand ſome principles in *Trochilicks*, or the art of Wheel-inſtruments. As chiefly, the relation betwixt the parts of a wheel, and thoſe of a Ballance; the ſeveral proportions in the Semidiameter of a wheel, being anſwerable to the ſides in a ballance, where the weight is multiplied according to its diſtance from the center. *Ariſt. Mechan. c. 2. De ratione libræ ad circulum.*

Thus



Thus suppose the center to be at *A*, and the Diameter of the wheel *D C*, to be divided into equal parts (as is here expressed) it is evident according to the former ground, that one pound at *C*, will equiponderate to five pound at *B*, because there is such a proportion betwixt their several distances from the Center. And it is not material whether or no these several weights be placed horizontally; for though *B* do hang lower than

than *C*, yet this does not at all concern the heavineſs, or though the plummet *C* were placed much higher than it is at *E*, or lower at *F*, yet would it ſtill retain the ſame weight which it had at *C*, becauſe theſe plummets (as is the nature of all heavy bodies) do tend downwards by a ſtraight line; So that their ſeveral gravities are to be meaſured by that part of the horizontal Semidiameter which is directly either below or above them. Thus when the plummet *C*, ſhall be moved either to *G* or *H*, it will loſe $\frac{1}{4}$ of its former heavineſs, and be equally ponderous as if it were placed in the ballance at the number 3; and if we ſuppoſe it to be ſituated at *I* or *K*, then the weight of it will lie wholly upon the Center, and not at all conduce to the motion of the wheel on either ſide. So that the ſtraight lines which paſs through the diviſions of the diameter, may ſerve to meaſure the heavineſs of any weight in its ſeveral ſituations.

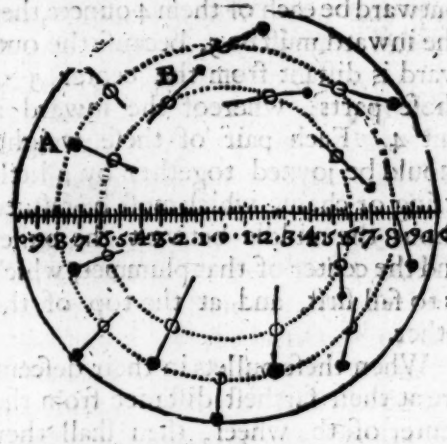
Theſe things throughly conſidered,

it

it ſeems very poſſible and eaſie for a man to contrive the plummets of a wheel, that they may be always heavier in their fall, than in their aſcent, and ſo conſequently that they ſhould give a perpetual motion to the wheel it ſelf: Since it is impoſſible for that to remain unmoved, as long as one ſide in it is heavier than the other.

For the performance of this, the weights muſt be ſo ordered, 1. That in their deſcent they may fall from the Center, and in their aſcent may riſe nearer to it. 2. That the fall of each plummet may begin the motion of that which ſhould ſucceed it. As in this following Diagram.

Where



Where there are 16 plummets, 8 in the inward circle, and as many in the outward, (the equality being to arise from their situation, it is therefore most convenient that the number of them be even). The eight inward plummets are supposed to be in themselves so much heavier than the other, that in the wheel they may be of equal weight with those above them, and then the fall of these will be of sufficient force to bring down

down the other. For example, if the outward be each of them 4 ounces, then the inward must be 5, because the outward is distant from the center 5 of those parts, whereof the inward is but 4. Each pair of these weights should be joyned together by a little string or chain, which must be fastned about the middle betwixt the bullet and the center of that plummet, which is to fall first, and at the top of the other.

When these bullets in their descent are at their farthest distance from the center of the wheel, then shall they be stopped, and rest on the pins placed to that purpose; and so in their rising, there must be other pins to keep them in a convenient posture and distance from the center, lest approaching too near unto it, they thereby become unfit to fall, when they shall come to the top of the descending side.

This may be otherwise contrived with some different circumstances; but they will all redound to the same effect.

effect. By such an engine it seems very probable, that a man may produce a perpetual motion. The distance of the plummets from the center increasing their weight on one side; and their being tyed to one another, causing a constant succession in their falling.

But now, upon experience I have found this to be fallacious; and the reason may sufficiently appear by a calculation of the heavinesse of each plummet, according to its several situations; which may easily be done by those perpendiculars that cut the diameter, (as was before explained, and is here expressed in five of the plummets on the descending side). From such a calculation it will be evident, that both the sides of this wheel will equiponderate, and so consequently that the supposed inequality, whence the motion should proceed, is but imaginary and groundless. On the descending side, the heavinesse of each plummet may be measured according to these numbers, (supposing the diameter

ameter of the wheel to be divided into twenty parts, and each of those subdivided into four).

The outward plummets.		*The inward plummets.*	
7 0		1 0	
10 0	*The sum* 24.	7 2	*The sum* 19.
7 0		3 0	

On the ascending side the weights are to be reckoned according to these degrees.

The outward.		*The inward.*	
1 3		4 1	
7 2		7 0	
9 0	*The sum* 24.	5 2	*The sum* 19.
5 3		2 1	
0 0			

The summe of which last numbers is equal with the former, and therefore both the sides of such a wheel, in this situation will equiponderate.

If

If it be objected, that the plummet *A* ſhould be contrived to pull down the other at *B*, and then the deſcending ſide will be heavier than the other.

For anſwer to this, it is conſiderable,

1. That theſe bullets towards the top of the wheel, cannot deſcend till they come to a certain kind of inclination.

2. That any lower bullet hanging upon the other above it, to pull it down, muſt be conceived, as if the weight of it were in that point where its ſtring touches the upper; at which point this bullet will be of leſs heavineſs in reſpect of the wheel, than if it did reſt in its own place: So that both the ſides of it in any kind of ſituation may equiponderate.

CAP. XV.

Of compoſing a perpetual motion by fluid weights. Concerning Archimedes *his water-ſcrew. The great probability of accompliſhing this inquiry by the help of that: with the fallibleneſs of it upon experiment.*

THat which I ſhall mention as the laſt way, for the trial of this experiment, is by contriving it in ſome water-inſtrument; which may ſeem altogether as probable and eaſie as any of the reſt, becauſe that element by reaſon of its fluid and ſubtil nature (whereby of its own accord it ſearches out the lower and more narrow paſſages) may be moſt pliable to the mind of the artificer. Now the uſual means for the aſcent of water is either by *Suckers* or *Forces*, or ſomething equivalent thereunto; Neither of which may be conveniently applied unto ſuch a work as this, becauſe there is required unto each of them ſo much or more ſtrength, as may be anſwerable

ble to the full weight of the water that is to be drawn up; and then beſides, they move for the moſt part by fits and ſnatches, ſo that it is not eaſily conceivable, how they ſhould conduce unto ſuch a motion which by reaſon of its perpetuity muſt be regular and equal.

But amongſt all other ways to this purpoſe, that invention of *Archimedes* is incomparably the beſt, which is uſually called *Cochlea*, or the *Water-ſcrew*, being framed by the Helical revolution of a cavity about a Cylinder. We have not any diſcourſe from the Author himſelf concerning it, nor is it certain whether he ever writ any thing to this purpoſe. But if he did, yet as the injury of time hath deprived us of many other his excellent works, ſo likewiſe of this, amongſt the reſt.

Athenæus ſpeaking of that great ſhip built by *Hiero*, in the framing of which there were 300 Carpenters employed for a year together, beſides many other hirelings for carriages, *Dipnoſoph.* l. 5.

and ſuch ſervile works, mentions this inſtrument as being inſtead of a pump for that vaſt ſhip; by the help of which, one man might eaſily and ſpeedily drain out the water, though it were very deep.

Biblioth. l. 1. *Diodorus Siculus* ſpeaking of this engine, tells us, that *Archimedes* invented it when he was in *Egypt*, and that it was uſed in that Country for the draining thoſe pits and lower grounds, whence the waters of *Nilus* could not return. Φιλοτέχνου δ' ὄντος τοῦ ὀργανου καθ' ὑπερβολὴν, (ſaith the ſame Author). It being an engine ſo ingenious and artificial, as cannot be ſufficiently expreſſed or commended. And ſo (it ſhould ſeem) the Smith in *Millain* conceived it to be, who having without any teaching or information found it out, and therefore thinking himſelf to be the firſt inventor, fell mad with the meer joy of it.

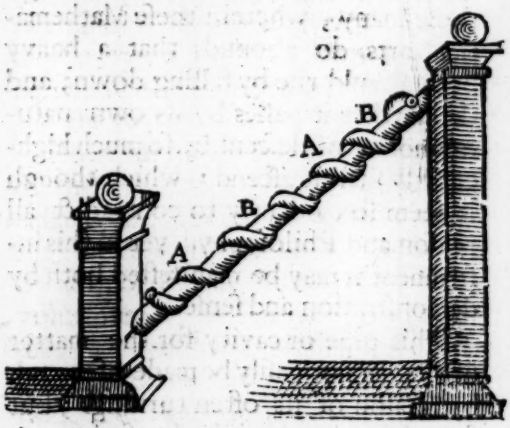
Cardan. Subt. l. 1: De ſapient. l. 5.

The nature and manner of making this, is more largely handled by *Vitruvius*.

Architect. l. 10. c. 11.

The

The Figure of it is after this manner.



Where you ſee there is a Cylinder *A A*, and a ſpiral cavity or pipe twining about it, according to equal revolutions *B B*. The axis and centers of its motions are at the points *C D*, upon which being turned, it will ſo happen that the ſame part of the pipe which was now lowermoſt, will preſently become higher, ſo that the water does aſcend by deſcending; aſcending in compariſon to the whole inſtrument, and deſcending in reſpect

of its ſeveral parts. This being one of the ſtrangeſt wonders amongſt thoſe many, wherein theſe Mathematical arts do abound, that a heavy body ſhould riſe by falling down; and the farther it paſſes by its own natural motion of deſcent, by ſo much higher ſtill ſhall it aſcend; which though it ſeem ſo evidently to contradict all reaſon and Philoſophy; yet in this inſtrument it may be manifeſted both by demonſtration and ſenſe.

This pipe or cavity for the matter of it, cannot eaſily be made of metal, by reaſon of its often turnings; but for trial, there might be ſuch a cavity, cut in a column of wood, and afterwards covered over with tin plate.

For the form and manner of making this ſcrew, *Vitruvius* does preſcribe theſe two rules:

1. That there muſt be an equality obſerved betwixt the breadth of the pipe, and the diſtance of its ſeveral circumvolutions.

2. That there muſt be ſuch a proportion

portion betwixt the length of the inſtrument, and its elevation, as is anſwerable to the *Pythagorical Trigon.* If the Hypotenuſal, or Screw be 5, the perpendicular or elevation muſt be 3, and the baſis 4.

David Rivalt. Com. in Archim. opera. extern.

However (with his leave) neither of theſe proportions are generally neceſſary, but ſhould be varied according to other circumſtances. As for the breadth of the pipe in reſpect of its revolutions, it is left at liberty, and may be contrived according to the quantity of water which it ſhould contain. The chief thing to be conſidered is the obliquity or cloſeneſs of theſe circumvolutions. For the nearer they are unto one another, the higher may the inſtrument be erected; there being no other guide for its true elevation but this.

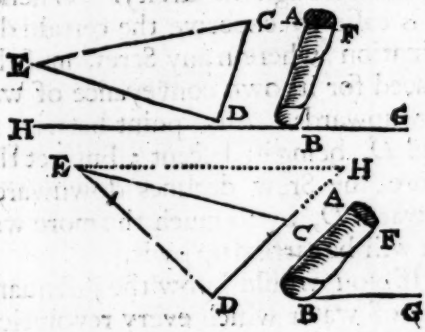
And becauſe the right underſtanding of this particular is one of the principal matters that concern the uſe of this engine, therefore I ſhall endeavour with brevity and perſpicuity to explain it. The firſt thing

to be inquired after, is what kind of inclination these Helical revolutions of the Cylinder have unto the Horizon; which may be thus found out.

Let *A B* represent a Cylinder with two perfect revolutions in it; unto which Cylinder the perpendicular line *C D* is equal: the basis *D E* being supposed to be double unto the compass or circumference of the Cylinder. Now it is certain that the angle *C E D*, is the same with that by which the revolutions on the Cylinder are framed; and that the line *E C*, in comparison to the basis *E D*, does shew the inclination of these revolutions unto the Horizon. The grounds and demonstration of this, are more fully set down by *Guidus Ubaldus*, in his Mechanicks, and that other

other Treatiſe *De Cochlea*, which he writ purpoſely for the explication of this inſtrument, where the ſubtilties of it are largely and excellently handled.

Now if this Screw which was before perpendicular, be ſuppoſed to decline unto the Horizon by the angle *EB G*, as in this ſecond Figure;



then the inclination of the revolutions in it, will be increaſed by the angle *E D H*, though theſe revolutions will ſtill remain in a kind of aſcent, ſo that water cannot be turned through them.

But

But now if the Screw be placed ſo far declining, that the angle of its inclination *F B G*, be leſs than the angle *E C D*, in the triangle, as in this other Diagram under the former; then the revolutions of it will deſcend to the Horizon, as does the line *E C*, and in ſuch a poſture, if the Screw be turned round, water will aſcend through its cavity. Whence it is eaſie to conceive the certain declination wherein any Screw muſt be placed for its own conveyance of water upwards. Any point betwixt *H* and *D*, being in deſcent; but yet the more the Srew declines downwards towards *D*, by ſo much the more water will be carried up by it.

If you would know the juſt quantity of water which every revolution does contain and carry, according to any inclination of the Cylinder, this may be eaſily found by aſcribing on it an *Ellipſis*, parallel to the Horizon; which *Ellipſis* will ſhew how much of the revolution is empty, and how much full.

See a further explication of this in *Ubaldus de Cochler, l. 2. prop. 25.*

The

The true inclination of the Screw being found, together with the certain quantity of water which every *Helix* does contain; it is further conſiderable, that the water by this inſtrument does aſcend naturally of it ſelf without any violence or labour, and that the heavineſs of it doth lie chiefly upon the centers or axis of the Cylinder, both its ſides being of equal weight (ſaith *Ubaldus*); So that (it ſhould ſeem) though we ſuppoſe each revolution to have an equal quantity of water, yet the Screw will remain with any part upwards (according as it ſhall be ſet) without turning it ſelf either way. And therefore the leaſt ſtrength being added to either of its ſides, ſhould make it deſcend, according to that common Maxime of *Archimedes*; any addition will make that which equiponderates with another, to tend downwards. *Ibid. l. 3. prop. 4.* *De Equipond. Suppoſ. 3.*

But now, becauſe the weight of this inſtrument, and the water in it, does lean wholly upon the axis, hence

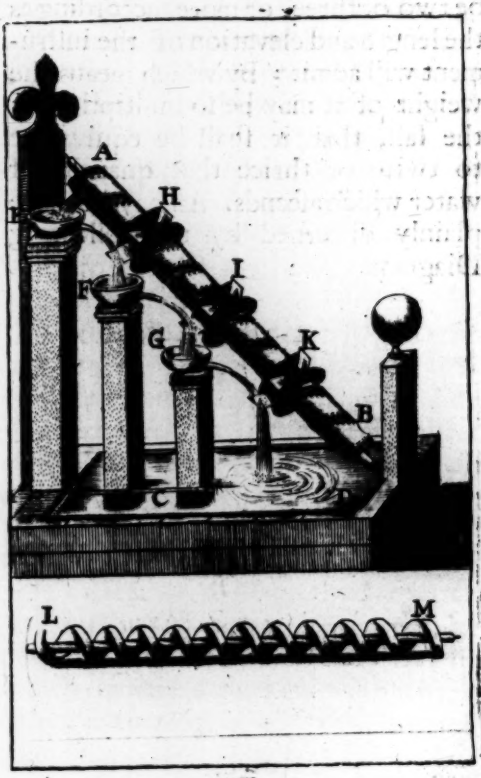
hence is it (saith *Ubaldus*) that the grating and rubbing of these axes against the sockets wherein they are placed, will cause some ineptitude and resistency to that rotation of the Cylinder, which would otherwise ensue upon the addition of the least weight to any one side; But (saith the same Author) any power that is greater than this resistency which does arise from the axis, will serve for the turning of it round.

These things considered together, it will hence appear, how a perpetual motion may seem easily contrivable. For if there were but such a water-wheel made on this instrument, upon which the stream that is carried up, may fall, in its descent it would turn the screw round, and by that means convey as much water up, as is required to move it; so that the motion must needs be continual, since the same weight which in its fall does turn the wheel, is by the turning of the wheel carried up again.

Or if the water falling upon one wheel

wheel would not be forcible enough for this effect, why then there might be two or three, or more, according as the length and elevation of the inſtrument will admit; By which means the weight of it may be ſo multiplied in the fall, that it ſhall be equivalent to twice or thrice that quantity of water which aſcends. As may be more plainly diſcerned by this following Diagram.

Where


A
H
E
I
F
G
K
B
C
D
L
M

Where the figure *L M*, at the bottome does repreſent a wooden Cylinder with Helical cavities cut in it, which at *A B*, is ſuppoſed to be covered over with tin plates, and three water-wheels upon it, *H I K*. The lower ciſtern which contains the water being *C D*. Now this Cylinder being turned round, all the water which from the ciſtern aſcends through it, will fall into the veſſel at *E*, and from that veſſel being conveyed upon the water-wheel *H*, ſhall conſequently give a circular motion to the whole Screw: Or if this alone ſhould be too weak for the turning of it, then the ſame water which falls from the wheel *H*, being received into the other veſſel *F*, may from thence again deſcend on the wheel *I*; by which means the force of it will be doubled. And if this be yet inſufficient, then may the water which falls on the ſecond wheel *I*, be received into the other veſſel *G*, and from thence again deſcend on the third wheel at *K*: and ſo for as many

There is another like contrivance to this purpoſe in *Pet. Bettin. Apiar.* 4. *Progym.* 1. *Prop.* 10. but with much leſs advantage than 'tis here propoſed.

many other wheels, as the inſtrument is capable of. So that beſides the greater diſtance of theſe three ſtreams from the center or axis, by which they are made ſo much heavier; and beſides, that the fall of this outward water is forcible and violent, whereas the aſcent of that within, is natural; Beſides all this, there is thrice as much water to turn the Screw, as is carried up by it.

But on the other ſide, if all the water falling upon one wheel, would be able to turn it round, then half of it would ſerve with two wheels; and the reſt may be ſo diſpoſed of in the fall, as to ſerve unto ſome other uſeful delightful ends.

When I firſt thought of this invention, I could ſcarce forbear with *Archimedes* to cry out εὕρηκα εὕρηκα; It ſeeming ſo infallible a way for the effecting of a perpetual motion, that nothing could be ſo much as probably objected againſt it: But upon trial and experience I find it altogether inſufficient for any ſuch purpoſe

purpoſe, and that for theſe two reaſons:

1. The water that aſcends will not make any conſiderable ſtream in the fall.

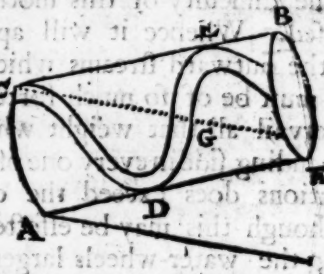
2. This ſtream (though multiplied) will not be of force enough to turn about the Screw.

1. The water aſcends gently and by intermiſſions, but it falls continuately and with force; each of the three veſſels being ſuppoſed full at the firſt, that ſo the weight of the water in them might add the greater ſtrength and ſwiftneſs to the ſtreams that deſcend from them. Now this ſwiftneſs of motion will cauſe ſo great a difference betwixt them, that one of theſe little ſtreams may ſpend more water in the fall, than a ſtream ſix times bigger in the aſcent, though we ſhould ſuppoſe both of them to be continuate; How much more then, when as the aſcending water is vented by fits and intermiſſions, every circumvolution voiding only ſo much as is con-

tained in one *Helix*? And in this particular, one that is not verſed in theſe kind of experiments, may be eaſily deceived.

But ſecondly, though there were ſo great a diſproportion, yet notwithſtanding the force of theſe outward ſtreams, might well enough ſerve for the turning of the Screw, if it were ſo that both its ſides would equiponderate, the water being in them (as *Ubaldus* hath affirmed). But now upon farther examination, we ſhall find this aſſertion of his, to be utterly againſt both reaſon and experience. And herein does conſiſt the chief miſtake of this contrivance. For the aſcending ſide of the Screw is made by the water contained in it, ſo much heavier than the deſcending ſide, that theſe outward ſtreams thus applyed, will not be of force enough to make them equiponderate, much leſs to move the whole. As may be more eaſily diſcerned by this figure.

Where



Where *A B*, repreſents a Screw covered over, *C D E* one *Helix* or revolution of it, *C D* the aſcending ſide, *E D* the deſcending ſide, the point *D* the middle. The Horizontal line *C F*, ſhewing how much of the *Helix* is filled with water, *viz.* of the aſcending ſide, from *C* the beginning of the *Helix* to *D* the middle of it; and on the deſcending ſide, from *D* the middle, to the point *G*, where the Horizontal does cut the *Helix*. Now it is evident that this latter part *D G*, is nothing near ſo much, and conſequently not ſo heavy as the other *D C*. And thus is it in all the other revolutions, which as they are either more, or larger, ſo

will the difficulty of this motion be increased. Whence it will appear, that the outward ſtreams which deſcend muſt be of ſo much force as to countervail all that weight whereby the aſcending ſide in every one of theſe revolutions does exceed the other; And though this may be effected by making the water-wheels larger, yet then the motion will be ſo ſlow, that the Screw will not be able to ſupply the outward ſtreams.

There is another contrivance to this purpoſe mentioned by *Kircher de Magnete, l. 2. p. 4.* depending upon the heat of the Sun, and the force of winds, but it is liable to ſuch abundance of exceptions, that it is ſcarce worth the mentioning, and does by no means deſerve the confidence of any ingenious Artiſt.

Thus have I briefly explained the probabilities and defects of thoſe ſubtil contrivances, whereby the making of a perpetual motion hath been attempted. I would be loth to diſcourage the enquiry of any ingenious Artificer,

Artificer, by denying the possibility of effecting it with any of these Mechanical helps; But yet (I conceive) if those principles which concern the slowness of the power in comparison to the greatness of the weight, were rightly understood, and throughly considered, they would make this experiment to seem (if not altogether impossible yet) much more difficult than otherwise perhaps it will appear. However, the inquiring after it, cannot but deserve our endeavours, as being one of the most noble amongst all these Mechanical subtilties. And (as it is in the fable of him who dug the Vineyard for a hid treasure, though he did not find the money, yet he thereby made the ground more fruitful, so) though we do not attain to the effecting of this particular, yet our searching after it may discover so many other excellent subtilties, as shall abundantly recompence the labour of our enquiry.

Treated of before, *l.* 1.

And then besides, it may be another encouragement to consider the pleasure

pleasure of such speculations, which do ravish and sublime the thoughts with more clear angelical contentments. *Archimedes* was generally so taken up in the delight of these Mathematical studies of this familiar *Siren*, (as *Plutarch* stiles them) that he forgot both his meat and drink, and other necessities of nature; nay, that he neglected the saving of his life, when that rude solder in the pride and hast of victory, would not give him leisure to finish his demonstration. What a ravishment was that, when having found out the way to measure *Hiero's* Crown, he leaped out of the Bath, and (as if he were suddenly possest) ran naked up and down crying εὕρηκα εὕρηκα! It is storied of *Thales*, that in his joy and gratitude for one of these Mathematical inventions, he went presently to the Temple, and there offered up a solemn sacrifice. And *Pythagoras* upon the like occasion is related to have sacrificed a hundred oxen. The justice of providence having

οἰκείας καὶ συνοίκου σειρῆνος. *Plutarch. Marcell. Joan. Tzetzes, Chil. Hist. 35. Valer. Maxim. l. 8. c. 7.*

ving ſo contrived it, that the pleaſure which there is in the ſucceſs of ſuch inventions, ſhould be proportioned to the great difficulty and labour of their inquiry.

FINIS.